UNIVERSITY *of* ALASKA ANCHORAGE

Arctic Domain Awareness Center

DHS Center of Excellence (COE)

Project Work Plan

Dr. Helena S. Wisniewski
Principal Investigator/Director

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PROJECT WORK PLAN
UAA DHS Center of Excellence (COE)
Arctic Domain Awareness Center (ADAC)
PI/Director Dr. Helena S. Wisniewski
Email: hswisniewski@uaa.alaska.edu

I. COE ADAC OBJECTIVE/PURPOSE

As stated by the DHS Science &Technology Directorate, *"*The increased and diversified use of maritime spaces in the Arctic - including oil and gas exploration, commercial activities, mineral speculation, and recreational activities (tourism) - is generating new challenges and risks for the U.S. Coast Guard and other DHS maritime missions.*"* Therefore*,* DHS will look towards the new ADAC for research to identify better ways to create transparency in the maritime domain along coastal regions and inland waterways, while integrating information and intelligence among stakeholders. DHS expects the ADAC to develop new ideas to address these challenges, provide a scientific basis, and develop new approaches for U.S. Coast Guard and other DHS maritime missions. ADAC will also contribute towards the education of both university students and mid-career professionals engaged in maritime security.

The US is an Arctic nation, and the Arctic environment is dynamic. We have less multi-year ice and more open water during the summer causing coastal villages to experience unprecedented storm surges and coastal erosion. Decreasing sea ice is also driving expanded oil exploration, bringing risks of oil spills. Tourism is growing rapidly, and our fishing fleet and commercial shipping activities are increasing as well. There continues to be anticipation of an economic pressure to open up a robust northwest passage for commercial shipping. To add to the stresses of these changes is the fact that these many varied activities are spread over an immense area with little connecting infrastructure. The related maritime security issues are many, and solutions demand increasing maritime situational awareness and improved crisis response capabilities, which are the focuses of our Work Plan.

UAA understands the needs and concerns of the Arctic community. It is situated on Alaska's Southcentral coast with the port facility through which 90% of goods for Alaska arrive. It is one of nineteen US National Strategic Seaports for the US DOD, and its airport is among the top five in the world for cargo throughput.

However, maritime security is a national concern and although our focus is on the Arctic environment, we will expand our scope to include other areas in the Lower 48 states. In particular, we will develop sensor systems, decision support tools, ice and oil spill models that include oil in ice, and educational programs that are applicable to the Arctic as well as to the Great Lakes and Northeast.

The planned work as detailed in this document addresses the DHS mission as detailed in the National Strategy for Maritime Security, in particular, the mission to Maximize Domain Awareness (pages 16 and 17.) This COE will produce systems to aid in accomplishing two of the objectives of this mission. They are: 1) Sensor Technology developing sensor packages for airborne, underwater, shore-based, and offshore platforms, and 2) Automated fusion and real-time simulation and modeling systems for decision support and planning. An integral part of our efforts will be to develop new methods for sharing of data between platforms, sensors, people, and communities.

II. METHODOLOGY

To achieve the COE's mission its team will develop methods to:

- Acquire more detailed information – Observe – Above the water, on the surface, under the water, and on the shore – using unmanned vehicles for a regional view – aerial (AeroVironment), on the water vehicles (Liquid Robotics), and under the water (MBARI), and satellite imagery for a broader view; along with human observer networks – CBONs.
- Organize the data – Orient and Decide - *Develop an intelligent System of Systems* to understand the data, and provide a format for rapid decision making - using more precise assessment and prediction models and data fusion methods.
- Disseminate actionable information in real time - the right information to the right people, at the right time, for action.

This approach involves research and technology development within the following four Themes – Maritime Domain Awareness, Maritime Technology Research, E2E, and Integrated Education. The COE is organized around the OODA Loop, Figure 7, which illustrates how the themes integrate with the products, and the output to stakeholders. It is a build-test-build approach, and E2E pulls it all together to create rapidly usable products and transition them to DHS and its stakeholders. For testing, we will partner with the Port of Anchorage to provide realistic demonstrations and testing in a cold-weather environment and then migrate to other locations for continued testing and evaluation. For example, product testing is also planned at Coast Guard facilities, where appropriate.

The four Themes have specific projects defined within them. This plan presents the Baseline, Objective/Purpose, Methodology, Stakeholder Engagement, Metrics and Milestones, Outcomes and Output, and Budget expenses for each of the projects within the Themes. The projects within the themes follow.

Theme 1 (Theme 2 in the FOA) - Maritime Domain Awareness. This Theme has 7 research projects:

a. Community Based Observer Networks for Situational Awareness (CBONs-SA).
b. High Resolution Modeling of Arctic Sea Ice and Currents.
c. Oil Spill Modeling for the Bering, Chukchi, and Beaufort Seas – providing high resolution now casting oil spill models.
d. Real-Time Storm Surge and Coastal Flooding Forecasting for Western Alaska.
e. Identifying, tracking and communicating sea-ice hazards in an integrated framework.
f. Mobile Maritime Domain Awareness using HFR in Remote Settings.
g. Monitoring intentional and unintentional catastrophic events: detecting oil spills and sea ice properties through measurements of the C and H_2O isotope geochemistry in winds.

Theme 2 (Theme 3 in the FOA) - Maritime Technology Research. This theme has 4 research projects:

a. Integrated Intelligent System of Systems.
b. SmartCam.
c. Low-Cost Wireless Remote Sensors for Arctic Monitoring.
d. New Class of propeller-driven Long Range AUV.

Theme 3 (Theme 5 in the FOA) - E2E - pulls it all together to create rapidly usable products and transition them to DHS. It is a build test build approach. The projects in E2E include those under development in Themes 1 and 2 in this document.

We propose to host the 2015 (May-June) USA-led Arctic Zephyr SAR table top exercise for Arctic Council members, permanent participants and observers. The event will be used to identify MDA and response gaps and best practices for responding to SAR events in the region.

Theme 4 (Theme 6 in FOA) - Integrated Education - to ensure effective training and develop a future work force that will address DHS needs through the following.

a. "ARCTIC Education: Implementing the Arctic Strategy in Training." Develop an ice navigation course with a simulator for training, and incorporate research results from Maritime Domain Awareness research, in particular "Arctic Sea Ice and Storm Surge Predictions" into the training software.
b. Minority Serving Institutions (MSI) outreach and integration into the ADAC.
c. Integrated Arctic Maritime Education.

III. CENTER MANAGEMENT TEAM AND PARTNERS

Renowned experts in engineering, science, entrepreneurs experienced in technology transition, and experienced executives from private industry (Figure 1) - an exceptional team to accomplish the proposed goals. As the Center Lead, UAA will assume the responsibilities of managing, coordinating, and supervising the entire range of Center activities; monitoring progress; and ensuring the implementation project evaluation and transition plan. UAA prides itself in its successful record of complex project management and outcomes and its ability to assure compliance with grant requirements through exceptional leadership and dedicated staff**.** The Committees that will be part of the evaluation and decision process are the Steering Committee and the Strategic Planning Committee (SPC). The Steering Committee will provide strategic guidance to ensure that the ADAC is achieving its intended goals, help decide which projects or tasks should be eliminated or added – this will be done in concurrence with DHS, and provide other advice and decision guidance as needed. The SPC will consist of the ADAC Director, Administrative Core Deputy Director, ADAC PI, Program Manager for Customer Advocacy and Transition, and a representative from each partner. The SPC will have an Executive Technology Sub-Committee comprised of the PI and Theme Leads, which will focus on the research themes and their integration into E2E.

Center management team:

COE Executive Director (COE/ED) – Dr. Helena Wisniewski will provide executive level oversight of the COE. She will chair the Strategic Planning Committee (SPC); provide semi-annual reports to the Steering Committee (SC), and work to ensure that the COE is responsive to the expectations of the DHS management team. She will serve as the COE conduit to senior management at UAA and partner institutions to advocate for the program and assure management's continuing support. She will meet regularly with the COE Director to discuss programmatic issues and solutions and where necessary serve to assist the director in meeting the COE programmatic goals. Where appropriate, she will support the DHS management team in representing the COE and its programs at national level meetings and within the DHS enterprise. She will devote up to 40% of her time.

COE Director (COE/D) – The full time COE/D will provide day-to-day direction of all Center activities and ensure that COE goals are met, milestones achieved, technology transitions are occurring, and the end users are satisfied with the results. He/she will organize site visits for demonstrations, interface with the end users, and ensure the Center is in compliance with all federal regulations and reporting and that there is appropriate utilization of funds by instituting a series of checks and balances with alerts. He will regularly meet with DHS staff at DHS headquarters and represent the program at meetings required to support the needs of DHS management and the greater DHS enterprise. Together with the PM for customer advocacy and transition, the COE/D will work closely with USCG stakeholders, and the USCG Research and Development Center (RDC) to ensure that the USCG expectations are being met; arrange for testing and evaluation of products developed by the Center, where appropriate; and ensure that USCG acquisition approves the needs of the products.

PM for Customer Advocacy and Transition – Realizing importance of ensuring customer satisfaction, meeting their requirements and successful transition to stakeholders, we created this position. The PM will be Charles Stuart, former DARPA Director, Maritime Systems Technology. At DARPA he was responsible for a $300M/year technology projects office. He will serve on the Strategic Planning Committee and report to the COE Director. He and the COE Director will meet with stakeholders, to ensure that they are: part of the transition planning process; planning cycle; satisfied with products; given the opportunity to suggest new directions and products. He will devote 30% - 40% of his time.

PM for Research – Dr. George Kamberov, UAA Assoc. Vice Provost for Research, will work with the research theme leads, and individual researchers. He will attend meetings with the Center Director where appropriate to interact with DHS and stakeholders and will interface with other DHS COEs and research centers to identify and formulate additional research projects. He will be part of the process to identify when research projects are ready to transition to the next TRL and suitable for E2E. He will serve on the SPC and devote 30% of his time.

Director for Integrated Education – Dr. Orson Smith, will interface with all the university partners, COE research Theme leads, MSIs, and the Director MSI to create research, educational and training programs in areas important to DHS and will serve on the SPC. He will devote 40% of his time.

Director for MSI – Ms. Marva Watson currently serves as the UAA Director of Diversity and will be part of the Center to ensure that MSIs are engaged. She will build on policies and practices already in place to develop and implement plans to engage MSIs. Ms. Watson is currently involved with attracting faculty and students from HBCUs to UAA, and participates in the “Institute on Teaching and Mentoring” conference sponsored by the Compact for Faculty Diversity, where UAA has successfully recruited outstanding faculty from MSIs. She will work closely with the COE Director, Director, Integrated Education, and Theme Leads and serve on the Strategic Planning Committee. Will devote up to 20% of her time, and additional when planning events for MSIs.

Research Integrity and Compliance – the UAA Research Integrity and Compliance Officer, Ms. Sharilyn Mumaw, who reports to the VPRGS, will provide oversight of COE compliance with the IRB, IACUC, and RCR committees to protect human and animal subjects and ensure the safe conduct of laboratory and research efforts. ITAR policies will also be applied where appropriate. She will serve on the SPC and devote 20% of her time.

Deputy Director for the Administrative Core and Fiscal Manager – This will be Erika Connor who is currently the Finance Director of the UAA ORGS. She will report to the COE Director and be responsible for management and oversight of administrative operations of the COE and group of associated subcontracts. She will provide program/project planning, budgeting, and implement operational policies and processes to support the COE. Develop budgets and manage expenditures as aligned with the research mission of the Center. She will serve on the SPC. She will devote 30% of her time, more when needed. A fiscal tech will be hired to assist with day-to-day admin tasks. Ms. Connor is the first level of fiscal/administrative oversight for the COE and will liaison routinely with Heather Paulsen, Director of UAA Office of Grants and Contracts and Sr. Grant Coordinator, Christine Mojica, who will monitor the business activities of the award through maintenance and control of financial records with integrated financial systems and statistical reports. For further description of the duties of the UAA Office of Grants and Contracts personnel, please visit the UAA website.

Director, MSARS E2E/R&T – Dr. Don Spalinger, UAA Professor, will interface with the research theme leads and researchers, with the PM for Customer Advocacy, and directly with stakeholders and customers to ensure successful transition and that the stakeholders are consulted and satisfied with products, and suggest new opportunities. Will attend meetings with stakeholders where appropriate and seek their input. He will be a member of the SPC. He will devote 40% of his time during the academic year, and full time during the 3 summer months.

PM for E2E – LuAnn Picard, UAA Professor of Program Management; prior to UAA managed large programs for HP. She will establish appropriate procedures for developing, selecting and/or continually evaluating the most promising homeland security-related research for transition to users. Will work closely with the Research PI, the PM for Research, and the Director and Co-Director for MSARS E2E/R&T (to whom she will report). She will serve on the Strategic Planning Committee. Will devote three months summer full time, and 40% during the academic year.

PI for Research – Dr. Kenrick Mock, UAA Chair, Computer Science & Engineering, will oversee the research theme directions, evaluate their progress and suggest new directions or eliminating current projects to the COE Director and the SPC. A member of the SPC and will work closely with the COE Director, MSARS/E2E and the PM for Research to integrate and transition research projects into the E2E. Dr. Mock will attend meetings with DHS and stakeholders to continue their engagement in the process. He will devote 30% of his time.

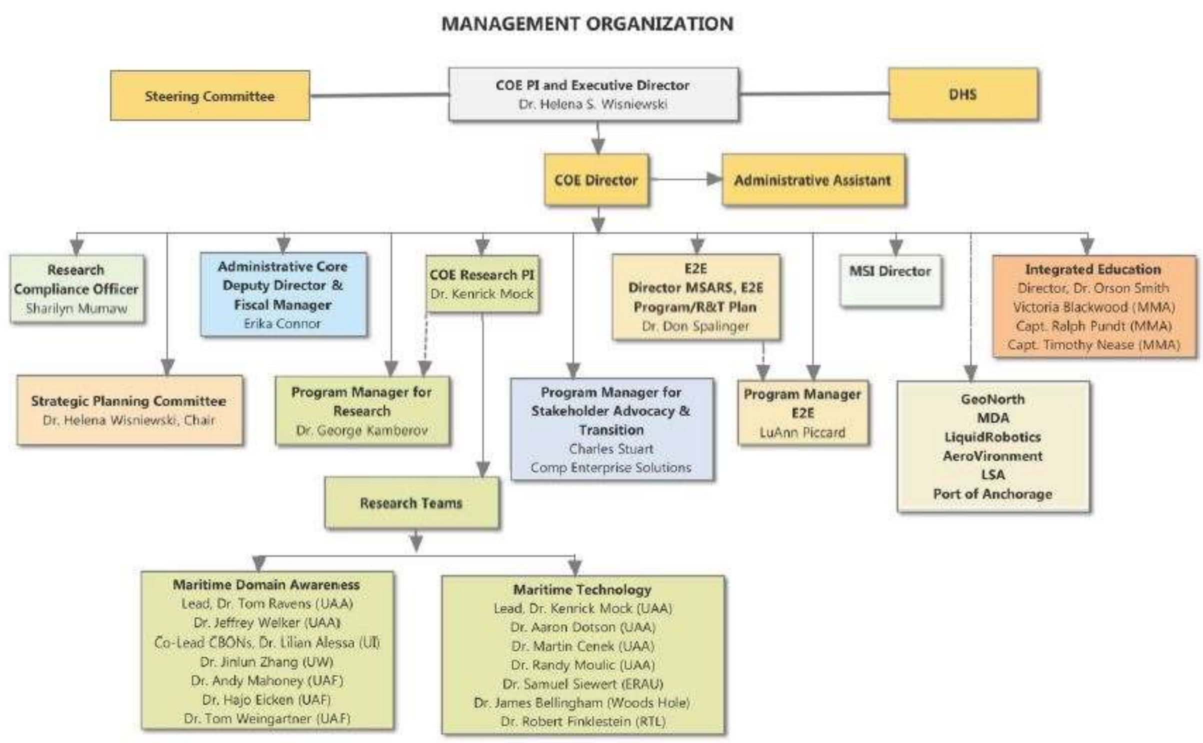

Figure 1: COE/ADAC Organization Chart

Center Partners- Geographically Distributed*:*

University partners

- University of Idaho

- University of Washington
- University of Alaska Fairbanks
- Maine Maritime Academy

Institutional Partners

- Monterey Bay Aquarium Research Institute (MBARI)
- Woods Hole Oceanographic Institute

Industry partners - bring capabilities, products and help to ensure transition

- MDA Systems (Canadian Company)
- GeoNorth (Alaska Native owned, 8A)
- Lockheed Martin
- AeroVironment
- Spectronn
- LSA Autonomy
- Liquid Robotics
- Robotic Technology Inc.

Cooperative Organizations

- US Coast Guard
- Port of Anchorage

IV. EVALUATION AND TRANSITION PLANS

1. **Rationale:** We propose a single E2E effort—Maritime Situational Awareness and Response Support (MSARS)–focused on DHS needs articulated in the *National Arctic Strategy Report to the President*, in the 2013 *US Coast Guard Arctic Strategy*, and in discussions among our federal cooperators, and municipal and industry collaborators (see Overview). Our program addresses the challenges confronting Arctic and Gulf of Alaska maritime stakeholders. The coastline of Alaska is the largest in the US. Together, they comprise an extremely large and diverse maritime theater. The challenges facing both maritime systems are similar, and thus models and lessons learned in each can be shared. However, the differences that exist provide a wide range of solutions for adaptation in many ports across the US. Use of our applications in the harsh arctic environment will also provide robust tests of new technology and systems.
2. **Goal:** Our MSARS E2E effort will develop, validate, and deploy innovative integrated systems to improve situational awareness and response capabilities to events that include man-made disasters (e.g. oil spills), natural disasters (e.g. tsunami, earthquake and flood) and terrorism (e.g. cruise ship hostage or port attack), and will provide a more secure, resilient, and efficient maritime environment and commerce.
3. **Methodology:** The MSARS E2E will develop and integrate extant and emerging maritime technologies and products proposed in Themes 1 and 2. We will enhance existing COTS platforms with new capabilities and design, develop new software platforms for application in a system of systems for maritime security. Air, ground and sea unmanned Vehicles (UXVs equipped with a spectrum of sensors, will be used to provide an economical, effective, and efficient set of force multipliers to conduct reconnaissance, surveillance, and target acquisition (RSTA) in the Arctic and Gulf for maritime security against adversarial and natural threats. A series of tasks conducted during the program, as described below, will culminate after tests, in a demonstration of UXV(s) in scenarios such as those mentioned in Section ii above. Our processes will provide continual assessment of outcomes and outputs, market potential, transition paths, intellectual property issues, legal and privacy issues.
4. **Organization of MSARS E2E effort:** Our effort is structured in the form of a conventional OODA loop: Observe, Orient, Decide and Act, see Figure ~~Figure~~ 7 below. MSARS data products

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and planning tool outputs will be “pushed” to users initially with the goal of transitioning the full functionality to user’s sites. To ensure relevancy, we initiated interaction with end users (e.g USCG, Port of Anchorage) during the proposal process and with DHS support, we will continuously expand that group and interact with the end user’s through a series of building and testing iterations. Our partner industries have provided proposal input, participated in meetings, and written letters of commitment. NOAA and NRL are contributing data to our oil spill and wave models in Theme 2. Tribal jurisdictions and Village Safety Patrol Officers will be involved in the UAA CBON effort as a part of MSARS. All stakeholders, including USCG RDC, will provide input and guidance through participation in the Strategic Planning Committee and direct interactions with the Program Managers and as part of the process shown in Figure 4.

5. **OBSERVE (Sensors and Communications)** These proposed products integrate both COTS from our industry partners, and develop new products that are proposed in Themes 1 and 2.

IV.a Evaluation Plan

Figure ~~Figure~~ 2 shows the process of how the UAA ADAC will continuously evaluate programs and projects, and a way to decide which ones should continue or be eliminated. The TRL Figure ~~Figure~~ 5 shows the process by which we determine a project is ready to continue to the next level of evaluation and progression.

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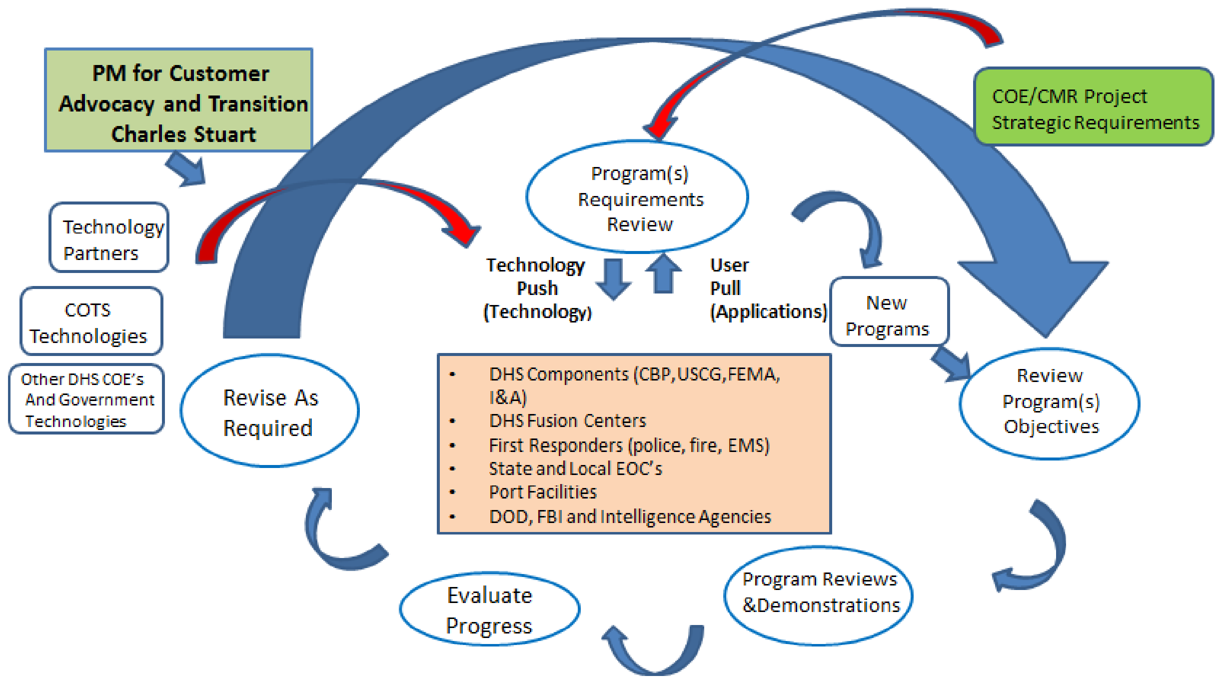

Figure 2: Our Evaluation Process is one of Continual Review

Administrative Activities of the COE. To assist the Center with program panning and management, the UAA ADAC team will continually record measures and metrics to reveal the current state of the effort. The efficiency of the administrative functioning of the Center depends on the collection of accurate and informative data. The data will concern two primary areas – fiscal accountability and schedule compliance.

i) Fiscal Accountability. The Administrative Core for the COE will track program actual expenditures for comparison with the expected expenditures from the program budget.

Quarterly reports will be used by COE leadership and theme and project leads to adjust activity levels to remain within 10% of projections. Projects that fall significantly behind may be terminated in favor or projects that show more promise, according to the Steering Committee.

ii) Schedule Compliance. The Administrative Core for the Coe will track actual progress for comparison with the expected progress from the program schedule. Quarterly reports will be used by the COE leadership, as well as, by theme and project leads to adjust activity levels to remain within 10% of projections. Projects that fall significantly behind may be terminated in favor or projects that show more promise, in accordance with discussions by the Steering Committee.

Projects in the COE. Projects will be evaluated using milestones, metrics and meeting the TRL and performance in a testing scenario. The individual Themes and E2E Tasks have performance metrics and milestones. We also have software tools to help define and evaluate metrics. A roll up of the milestones with dates is in Appendix A. Outcomes and Output are also presented for each project. However, the overall outcome is to fulfill our mission.

Budget. A budget is provided for each Project within a Theme and a roll up total program budget is shown in Appendix B. Regarding contractual services, these will be used as needed for testing, verification and validation of sensing devices and models, as presented within the projects, and will be provided by MDA Corporation, AeroVironment, Lockheed Martin as indicated in the original proposal.

Projects can fail in one of the following ways:

i) Fall significantly behind in schedule for delivery.
ii) Failure to meet milestones within a reasonable time – within 10% of the projection.
iii) Failure to meet provided metric, unless the project team sheds light on a new approach that is more beneficial.
iv) Inability to progress to the next TRL.

Projects that fail any of the conditions will be put on notice. If a get well plan can be provided that will fix the problem within a reasonable time frame, then it will be given a probationary period to do so. If that is not possible, then it will be considered for termination in favor of a project that shows more promise. This decision will be made in consultation with the Executive Director, Director, Center Lead, and the Steering Committee.

Evaluation of Functional Performance in the COE. The UAA ADAC team will evaluate the functional performance of the COE in three separate programs – Research Program, E2E Program and the Education Program (Figure ~~Figure~~ 3). For each project in the three programs, the leads will make timely reports of functional progress in addition to the financial and schedule reports above. Variations from the expected results need explanation. The Steering Committee will use these reports to help determine whether projects should be terminated in favor of other efforts.

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The Steering Committee will also depend on customer feedback to complete its evaluation of the progress of projects. A key metric in this regard will be tech push and user pull through continual discussions with the customers.

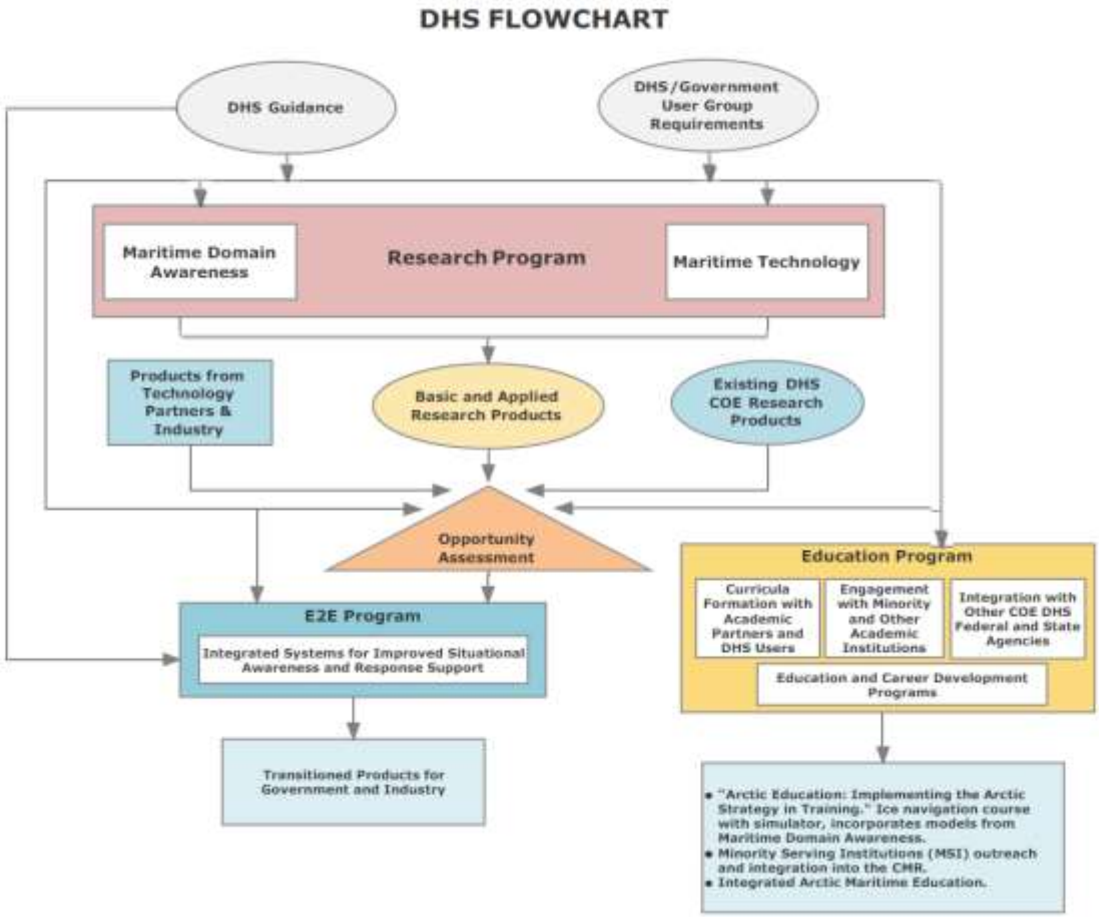

Figure 3: Research, MSARS E2E, and Education Evaluation Process

Evaluation of the Research Program. To support the Center with evaluating the progress of the core functional activities of the effort, the UAA ADAC team will continually record measures and metrics to reveal the progress made on all the projects contained in the effort. The metrics are project specific and are not listed in this section. However, the Center will produce quarterly reports of progress in each of the two main research areas, indicted in Figure ~~Figure~~ 3, summarizing the success of the group of projects contained in each research area. The measures and metrics are specific to the projects aligned with the goals presented in the Transition plan.

i) Maritime Domain Awareness.
ii) Maritime Technology

Evaluation of the E2E Program. Figure ~~Figure~~ 3 shows that the E2E program consists of one project. The measures and metrics are specific to the projects aligned with the goals presented in the Transition plan. The Center will produce quarterly reports of the progress of the contained projects.

At the core of our evaluation planning are the stakeholders who will have representation on the Steering Committee, Strategic Planning Committee (SPC) and Transition Planning and Implementation Committee (TPIC). The COE's primary stakeholder is DHS, and includes the Science and Technology Directorate, USCG (Pacific, Atlantic commands) and the Coast Guard Research and Development Center, and USCG Headquarters Acquisition Directorate. Additional current stakeholders include the ports of Anchorage and the Gulf. With these stakeholders in mind the COE will follow the following procedure for project evaluation.

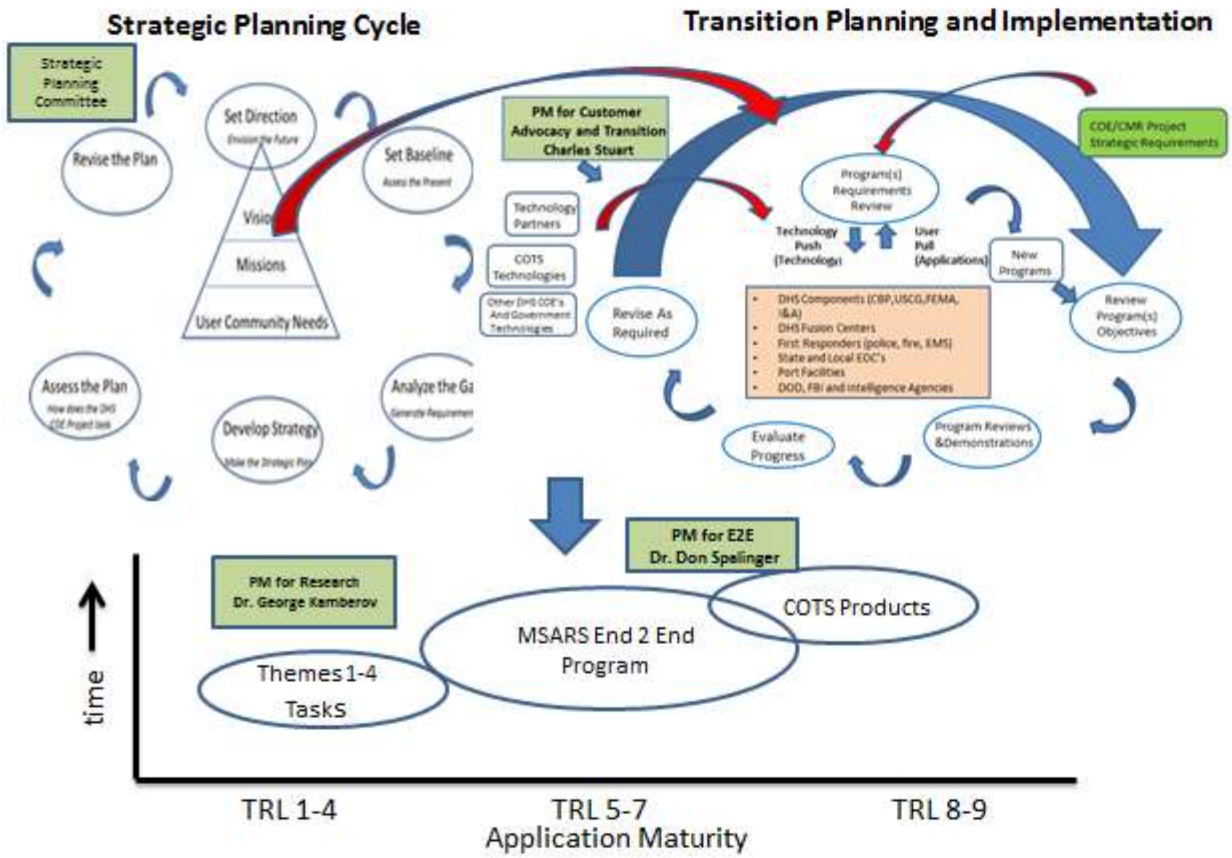

Figure 4: Planning Cycle for Ensuring Program Relevance and Rapid Transition

Procedure #1 *represents the steps to be followed by the Strategic Planning Committee to develop and continuously evaluate how well a given COE research project has performed versus the plan for the project.* It provides implementation of the activity entitled *Assess the Plan*. (Ref. Figure ~~Figure~~ Strategic Planning Cycle portion - also P. 10 of the proposal) This evaluation will occur for each project on a semi-annual basis.

- *Participants.* The participants for this procedure shall be the members of the SPC.
- *Inputs:* The inputs used for this procedure will be one or more of the following from a particular project.

1. Does the project (or its revision) continue to be aligned with the Sponsor's (DHS) mission?
2. Are stakeholders needs being met?
3. If still in the research phase, does it represent a duplication of efforts at other COEs or in the research community?
4. How much of the plan work was completed in the past cycle? Have all major milestones been met?
5. What are the current benefits vs costs?
6. When appropriate, does the project's plan include steps to commercialize the product? If so how much has been completed and has a market assessment been completed?
7. Using the technology maturity model as a guide, is the research or product ready for transition to the next TRL level?
8. Is there a stakeholder interested in transitioning/purchasing the product?

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9. What are the recommendations from the TPIC?

- *Output:* The output from executing this procedure shall be a written Progress and Performance Evaluation for the project to be used by the Strategic Planning Committee for the next steps in its cycle, *Revise the Plan* and *Set Direction* (Ref. Figure ~~Figure~~ 4 – also in the proposal p.10).
- *Steering Committee Oversight*. If the SPC's recommendation would cause a change of more than ten percent in a project's activities of budget for the next evaluation period, or if the recommendation is to discontinue the project, then this recommendation must receive the concurrence of the Steering Committee.

IV.b Transition Plan

All projects will be evaluated in the context of TRL maturity levels. MSARS will focus on rapid maturation of Themes 1 and 2, and COTS products into fieldable systems. Figure ~~Figure~~ 3 provides context for that process. Our research products currently stand at approximately TRL 4 maturity, and the MSARS process will push that technology to TRL7 or better, where it can be provided to an industry partner for productization and/or transitioned to a government customer where productization is not warranted. Our overall process is presented in this section in Figure ~~Figure~~ 6.

The Transition Plan, illustrated in Figure ~~Figure~~ 6, incorporates the maturity model discussed above, and the loop shows the "build-test-build" concept for product development. It illustrates where the requirements originate, the critical interactions with the end user, and how the technology developed in the themes, together with COTS from our industry partners, are used in the development cycle. We recognize the importance of the MSARS E2E effort and will assign a special PM to manage it. We also recognize the importance of customer transition and will assign a PM for customer advocacy to focus on customer interfaces, solicit requirements, provide support in demonstrations and transition agreements and ensure satisfaction with MSARS products.

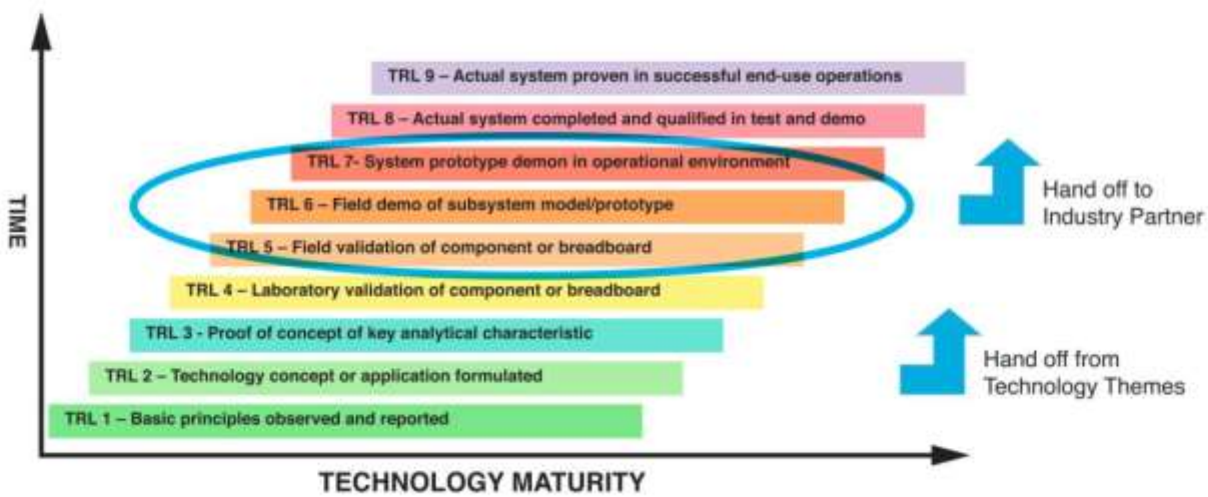


Figure 5: MSARS is focused on rapid maturation and transition of our technologies

The COE has an experienced team in technology transition commercialization. UAA is dedicated to commercializing faculty and student research and bringing it to market to benefit the economic growth. The proposed DHS COE ADAC Director, Dr. Wisniewski, experienced with launching and selling technology start-ups, implemented a commercialization infrastructure at UAA that will be beneficial to this effort (Ref. Management Plan).

Potential transition paths - The Center Lead, UAA, has relationships with end users, and involved them in the proposal planning process and partner meetings, to ensure that the proposal was identifying their needs. Some of them will serve on the Steering Committee, and will involve these identified end users, as well as additional ones, throughout the product development process to ensure that transition takes place and that transition strategies are meeting their needs. Current end users include the US Coast Guard, FBI, and Port of Anchorage.

At the core of our transition planning are the stakeholders who will have representation on the Steering Committee, Strategic Planning Committee (SPC) and Transition Planning and Implementation Committee (TPIC). The COE's primary stakeholder is DHS, and includes the Science and Technology Directorate, USCG (Pacific, Atlantic commands) and the Coast Guard Research and Development Center, and USCG Headquarters Acquisition Directorate. Additional current stakeholders include the ports of Anchorage and the Gulf. With these stakeholders in mind the COE will follow the following procedure for project transition.

Procedure #2 *represents the steps to be followed by the Transition Planning and Implementation Committee (TPIC) to determine whether a given Center project is ready for transition to Users/Stakeholders of the COE.* It provides implementation of the activity entitled *Evaluate Progress*. (Ref: Fig. 1- Transition Planning and Implementation portion- also p. 10 of the proposal.) This determination should occur for each project on a semi- annual basis.

- *Participants.* The participants for this procedure shall be the members of the Transition Planning and Implementation Committee (TPIC) – that will consist of representatives from stakeholders, the sponsor, The COE Executive Director, COE Director, Director E2E, Co-Director E2E, the PM for E2E, and Chaired by the PM for Customer advocacy. They will meet every six months and provide a written report with recommendations to the SPC.
- *Inputs:* The key inputs used for this procedure to determine transition readiness will be one or more of the following for a particular project.

1. Is the sponsor still interested and involved in the development process – is it still aligned with the Sponsor's mission?
2. Has the project been tested?
3. Has it been tested in the presence of the customer?
4. Did it meet performance criteria during the testing? Has the USCG Research and Development Center been involved in the testing and evaluation?
5. Does it meet customer requirements?
6. If not, can it be revised?
7. Is additional testing required?
8. Is there a stakeholder interested in transitioning/purchasing the product?
9. What is the time and expenditure required to effect deployment of the project?
10. Where is it on the TRL maturity model? What is required to get it to the next level?
11. Market assessment – is there a demand for this project beyond the immediate customer?
12. Will it be commercializable? If so, implement the successful UAA commercialization infrastructure and process defined for developing IP. Inputs to measure end-user success will be integrated into future project activities for continuous process improvement.

- *Output:* The output from executing this procedure shall be a written recommendation as to whether the project is ready for and can be effectively transitioned to one or more end users. Progress reports on the project will be provided to the Strategic Planning Committee and Steering Committee every six months.
- *Steering Committee Oversight*. Recommendations from the TPIC to deploy a project must receive the concurrence of the Steering Committee.

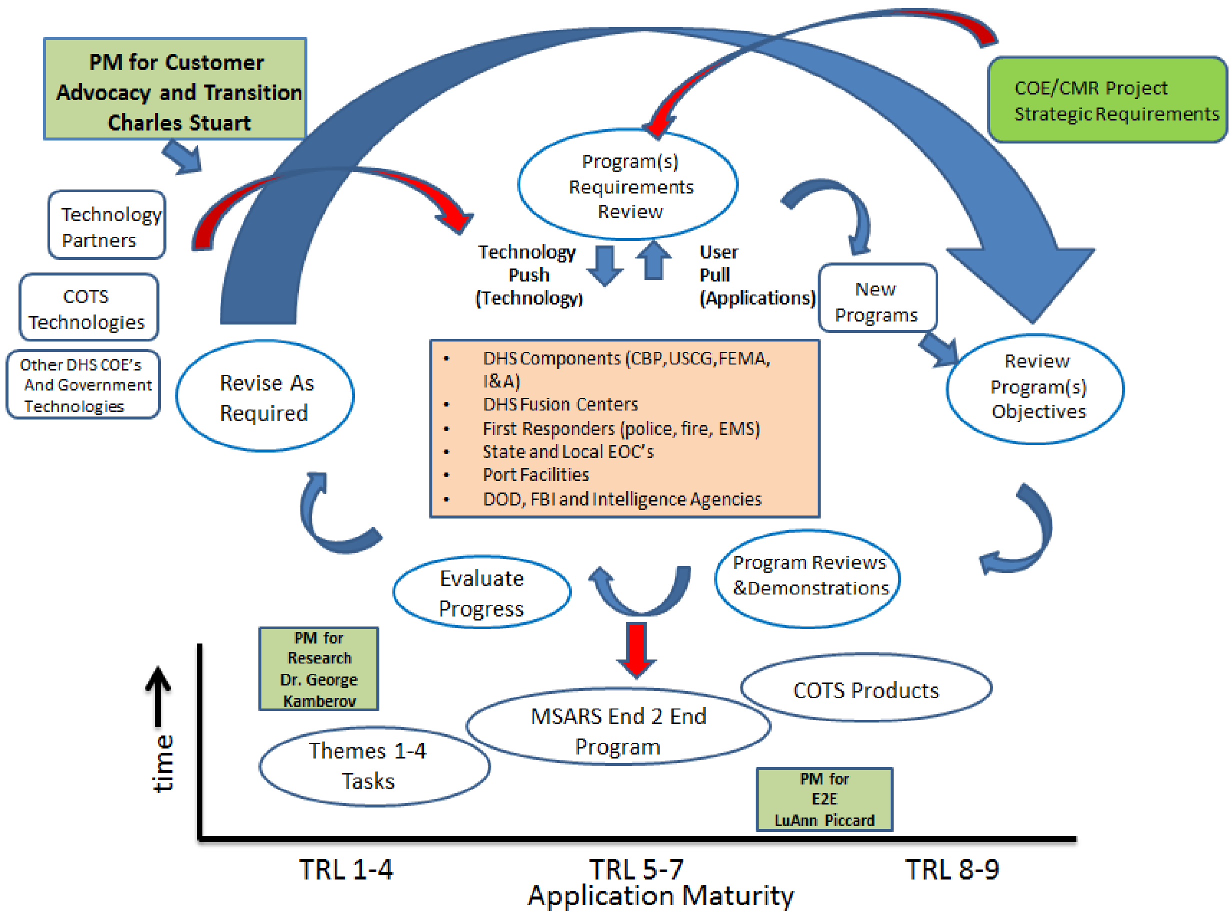


Figure 6: Technology implementation and transition process

V. USCG STAKEHOLDER ENGAGEMENT

Stakeholder engagement to date includes Admiral Abel, Commander, 17th Coast Guard District; Captain Evans Commanding Officer at USCG Research and Development Center; Mr. Bert Macesker, Executive Director, U.S. Coast Guard R&D Center; Mr. Mark VanHaverbeke Research Engineer U.S. Coast Guard Research & Development Center. Additional stakeholder engagement is in the DHS Science & Technology Directorate, Stephen Dennis, Innovation Director, Big Data and Analytics, Homeland Security Advanced Research Projects Agency. Additional stakeholders include NOAA.

The US Maritime Domain Awareness Top 20 **Challenges** that we reference in the Themes and associated projects are in Appendix C. We have addressed nine of the twenty challenges within the various projects or 45%.

We propose to host the 2015 (May-June) USA led Arctic Zephyr SAR table top exercise for Arctic Council members, permanent participants and observers. The event will be used to identify MDA and response gaps and best practices for responding to SAR events in the region.

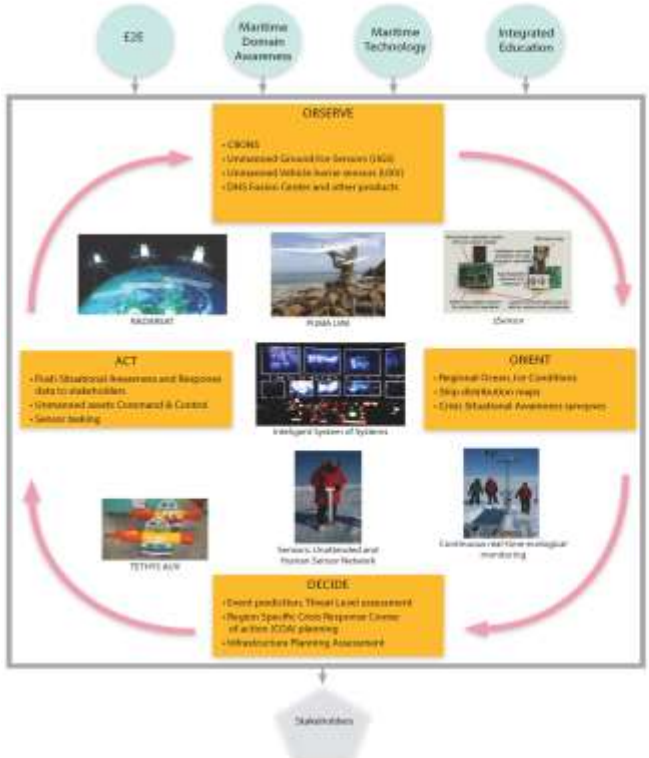


Figure 7: OODA Loop

VI. WORKFORCE DEVELOPMENT STRATEGY

This strategy involves both undergraduate and graduate students and current professionals for specialized training in Maritime Domain Analysis areas. Helping to attract students to STEM careers is a major component of the strategy, as the mission need is overwhelmingly for persons educated in the STEM fields. In particular, training in Arctic Engineering (a specialty of UAA) is a clear need for the UAA COE. Other specialized training includes Arctic Navigation – incorporating knowledge of sea ice behavior, as well as understanding how GPS behaves at high latitude.

More general aspects of the strategy involve generating interest in DHS and its components, such as the Coast Guard. The COE will host various "career days" with emphasis on the needs of DHS and its partners. Diversity will also be an objective of the strategy, with a "diversity day" included in the center's offerings. Because UAA has formal links via the WWAMI consortium, the strategy will also involve recruiting students (particularly for graduate and continuing education courses) to DHS friendly careers. We will use social media, direct contacts with organizations and employees within the DHS enterprise and the UAA system for tracking graduates that provides data to that includes long term tracking to keep our education programs current and will be used for this effort to help assist our graduates for successful careers in the DHS enterprise.

The strategy will also depend on participation of DHS personnel. Direct contact by students with DHS representatives at the various "days" will likely promote a positive expectation for DHS work.

VII. INDIVIDUAL WORK PLAN BY PROJECTS WITHIN A THEME

VII.1 Theme 1 – Maritime Domain Awareness Project

Theme Lead – Dr. Thomas Ravens, University of Alaska Anchorage (UAA)
Email: tmravens@uaa.alaska.edu

VII.1.a PROJECT - Community Based Observer Networks for Situational Awareness (CBONS-SA)

Principal Investigator: Dr. Lilian Alessa, University of Idaho

Abstract
An increasing number of mid-size vessels seem to appear and then disappear in the Bering Sea area, and these have been sighted by Alaska natives. Networks of human observers provide a unique opportunity to systematically observe and document Arctic environmental and globalization changes and, in particular, vessel tracking, waterway uses, incursions, arctic sea ice and storm surge, alerts to intentional and unintentional catastrophic events. New methods are needed to enhance the communication capabilities of the observers and to incorporate robotic platforms with the CBON-SAs. The existing framework and methodology needs to be expanded to cover new geographic areas as well as additional observational categories.
This project addresses US MDA Challenges 1,2,4,5, and 8. By providing "eyes on the sea" CBON-SA will support collection of observations of vessels that may not be emitting position (MDA Challenge #1) and vessels exhibiting unusual or anomalous behavior (MDA Challenge #5). The communications relay of these observations and behaviors will enable fusion and analysis with remote detection observations and data (MDA Challenge #2) and their subsequent integration to broader situational awareness analyses (MDA Challenge #8) providing a better understanding of maritime activity (MDA Challenge #4).

Baseline
The baseline for this project is the **Existing Community Observation Network** on St. Lawrence Island. It has demonstrated integration of community-based sea ice observations with the Arctic ERMA (Environmental Response Management Application) - a web based GIS tool for emergency responders. This baseline represents TRL 3 for the CBON-SA.

Objective/Purpose
The purpose of the CBON-SA is to utilize distributed human observers as sensors to systematically observe and document Arctic environmental and globalization changes, which are of significance to understanding resource security. By placing them in sociocultural and economic contexts, end users will be able to anticipate, plan and respond to these changes through a decision support system consisting of an integrated data suite. CBON data will be considered in conjunction with other observational data from satellite, radar, UAV and buoy-based instruments.

The CBON-SA will be used to advance research on the ability to utilize High Fidelity Observers (HFOs) to detect and put into context a range of critical variables that are critical to maritime security under different environmental conditions, and to develop reliable data streams, in real time, that are compatible with other monitoring data streams while retaining the added value of contextual description.

Benefits/relevance to DHS

The CBON examines environmental change and human activity in the Bering Strait region within a framework of a social-ecological system (SES). An SES is defined as a combination of biophysical components of the environment and of socio-cultural, geo-political processes that interact simultaneously such that they are fully interdependent (Chapin et al. 2009; Cummings 2011; Alessa et al. 2008). By making observations at the community scale, where residents have an intimate knowledge of the arctic marine setting, we are able to develop a data set that is otherwise not possible.

Methodology

For Year 1 we will employ qualitative and quantitative structured data intake templates (surveys), image tagging and systematic description codes; up-loading data via cell-to-satellite phone relays to the central database at UAA; and data sharing with the Alaska Ocean Observing System (AOOS) as appropriate, verifying data using MDA Corporation RADARSAT for applications such as verifying data regarding vessels without AIS.

We recognize that communication capabilities are an issue in remote areas of Alaska. Therefore, we will use the contractual services by Spectronn to study opportunistic networking. This would present the possibility of using the Lockheed Martin 74K Aerostat and, in the future, the Quintillion Arctic fiber network to increase the potential networking footprint for CBONS and other uses. The US Army has offered to provide two Aerostats at little or no cost to DHS, and discussions have been initiated with Lockheed, and US Army NORTHCOM to determine its feasibility.

For Year 2 we will revise the qualitative and quantitative structured data intake templates (surveys) based on Year 1 outcomes.

A scenario for a vessel tracking pilot to be completed at the end of year one is presented in the E2E Theme in this document.

Stakeholder Engagement

The CBON-SA team will engage with the Coast Guard to collaboratively assess and evaluate the feasibility to situate community response as part of a national effort. To date individuals at USCG include Rear Admiral Abel and Mr. Bert Macesker.

Milestones Year 1

1. Completed development and documentation of data intake templates.
2. Completed mapping of communication relays.
3. Completed successful testing of cell-to-satellite phone image capture and upload.
4. Completion of HFO training and certification.
5. Completion of HFO protocols for observation and transmittal.
6. Completed plan to enhance communication capabilities for observers.
7. Completed plan to incorporate unmanned robotic vehicles with CBONS – AeroVironment PUMA is a consideration.
8. Completed pilot scenario for vessel tracking.

Milestones Year 2

1. Completed expansion of the network to two communities.
2. Completed replication of Year 1 protocols to a second Bering Sea / Aleutian community.
3. Establish an operational CBON-SA.
4. Completed Expansion of existing framework, methodology with additional observation categories and additional areas.
5. CBON-SA integrated into the Intelligent Integrated System of systems (IISoS).

Metrics for Year 1 and 2

1. Number of successful image and data relays across the Bering transit: 10 - 15
2. Inter-rater reliability of observers: 0.7 – 0.9
3. Number of successes of triangulating and integrating HFO data with satellite and buoy data: 5 - 10
4. Number of successes to detect anomalous or unusual events (as defined in conjunction with stakeholders) with sufficient information - use satellite data from MDA Corporation to confirm: 3 – 6.

Outcomes, Output and TRLs

Year 1 Outcomes and Output

1. Pilot data flows and datasets consisting of images, meta-data, narratives and context that are spatially explicit (output). Metric 1. Expected 10-12 successful data relays. This represents TRL 5.
2. A tested protocol for HFOs to observe, detect, and record a range of variables that aid in vessel tracking under different environmental conditions (outcome). Field validations of this protocol will include triangulating and integrating HFO data with satellite and buoy data. Metric 3. This represents TRL 5.
3. An operational communication system for real time data flows from offshore HFO (outcome). Metric 1. Up to 15 successful data relays in the field. This represents TRL 5.
4. A successful pilot for vessel tracking. The CBON vessel tracking data is confirmed by the MDA Corporation. Metric 4.

Year 2 - Outcome

1. An operational CBON comprising two Bering Sea communities (one Northern Bering Sea; one Southern Bering Sea) that apply tested protocols for HFOs and demonstrates real-time transmission of observations. (Metrics 1, 2, 3, and 4). This represents TRL 7.

VII.1.b PROJECT – High Resolution Modeling of Arctic Sea Ice and Currents

Principal Investigator: Dr. Jinlun Zhang, Polar Science Center, Applied Physics Laboratory, University of Washington

Abstract

This project will develop an accurate, high resolution regional High-resolution Ice-Ocean Modeling and Assimilation System (HIOMAS) using the Regional Ocean Modeling System (ROMS), which allows for the development of nested grids. This system is to be calibrated and validated and then used for daily-to-seasonal forecast of Arctic Ocean currents, sea ice, and change. Accurate, high-resolution predictions of ocean currents and sea ice conditions will enhance the Coast Guard's ability to prepare for and respond to oil spills in the Arctic Ocean. These data will also allow the Coast Guard to more safely and reliably conduct search and rescue missions. Finally, the data will eventually will be transmitted to ship captains via the AIS system in order to promote safer maritime transportation.

Baseline

There are ice-ocean models on global or hemispheric scales. These models provide data on current velocity, ice thickness, ice concentration, and ice drift. The Hybrid Coordinated Ocean Model (HYCOM) – built by a consortium - is an example of such a model. It has a spatial resolution of about 4 km in the Chukchi and Beaufort Sea areas. However, the HYCOM model is not currently an operational model (gnome.orr.noaa.gov/goods). The Bering Eco System Study Modeling and Assimilation System (BESTMAS) – developed by Jinlun Zhang (Univ. of Washington) – is a validated, ocean/sea ice model with a 4 km resolution in areas along Alaska coast in the Beaufort Sea and coarser resolutions in other parts of the Arctic Ocean. BESTMAS has been operated in hind-cast mode. The new model will be a forecast model and high resolution for realistic prediction of sea ice conditions.

Objectives

The principal research objective is to develop a new HIOMAS model based on the ROMS model system. The ROMS model system has excellent nesting capability, which will, eventually, enable the development of very high resolution output in the Chukchi/Beaufort Sea area (to target resolution of 2 km). However, the objective in the first two years is to develop the modeling framework including establishing the boundary conditions and the forcing data. The new HIOMAS model will be calibrated and validated using available observations of ice thickness, concentration, and drift. Observations of ocean temperature, salinity, and velocity will also be used to validate HIOMAS results. In particular, the simulated ocean currents will be validated using HF Radar-derived current data to be collected by other investigators within the overall project. Once the new, ROMS-based HIOMAS model has been calibrated and validated, it will be revised, in subsequent years, to achieve higher resolution output in the Chukchi Sea and Beaufort Sea area. Also, subsequently, HIOMAS will be used for sea ice forecast with lead times ranging from one day to one season.

Student involvement - A post-doc will be involved in model configuration, calibration, and validation in year 2.

Methodology*:* Quantitative. Continuous testing and validation using sensors developed in the Maritime Technology Theme and unmanned autonomous vehicles, and satellite data from MDA Corporation RADARSAT.

Key Stakeholder: Champion: USCG - Mr. Mark Everett and Mr. Rob Haynes (US Coast Guard, 17^{th} Coast Guard District).

US MDA Challenges addressed: 4, 8, 16.

Benefits

Will enhance the Coast Guard's ability to prepare for and respond to oil spills in the Arctic Ocean, to more safely and reliably conduct search and rescue missions, and will eventually be transmitted to ship captains via the AIS system in order to promote safer maritime transportation.

Metrics & Milestones

Milestones Year 1

1. Complete a survey of data products that may be used as forcing to drive HIOMAS or as open boundary conditions;
2. Complete plan on model configuration.

Milestones Year 2

1. Completion of HIOMAS at a relatively coarse resolution to allow for rapid testing of model.
2. Complete model calibration and validation using
    a. Satellite ice concentration data from the National Snow and Ice Data Center (NSIDC),
    b. Buoy drift data from the International Arctic Buoy Program (IABP), and
    c. Available HF Radar-derived current data from collaborating investigators of this project.
3. Successful launching of the new ROMS-based arctic sea ice and current model, with nested grid capability (HIOMAS)
4. Model data integrated into the IISoS

Metrics

1. Model resolution at locations of high interest. Current resolution: 4 km; target: 2 km.
2. Mean prediction error in ice concentration (percent). Current estimate: 50%; target: 25% (or better).
3. Mean prediction error in ice thickness (m). Current error: 2 m; target 1 m (or better).
4. Mean error in ice drift velocity estimates (m/s). Current error: 2 m/s; target 1 m/s (or better).

Outcomes/Output and TRLs

The baseline and target Technology Readiness Levels for this project are 2 and 3, respectively. We are currently at Level 2. We plan to reach Level 3 at the end of year 1. We plan to reach Level 6 at the end of year 2.

Develop and deploy high resolution (target: 2 km) HIOMAS model of ocean currents and sea ice using ROMS model system/high resolution predictions of sea ice thickness, concentration, and drift, and surface ocean currents, temperature, and salinity (and assessments of those predictions).

VII.1.c PROJECT: Oil Spill Modeling for the Bering, Chukchi, and Beaufort Seas

Principal investigator*:* Dr. Tom Ravens, UAA

In the event of an oil spill, the US Coast Guard is in charge of response operations. The US Coast Guard receives scientific guidance on oil spills from NOAA's Office of Response and Restoration based on General NOAA Operational Modeling Environment (GNOME) and other resources. UAA will directly support the US Coast Guard by providing high-resolution ocean current and sea ice data in GNOME-compatible format. Further, we will assist NOAA and the Coast Guard by providing guidance on how to incorporate ice data within GNOME. Finally, we will gather and analyze available data on oil spill fate and transport in the arctic and make recommendations to NOAA on how to incorporate that data within GNOME.

Baseline

The baseline for this project is NOAA's oil spill modeling software including GNOME, NOAA's Office of Response and Restoration supports oil spill preparedness and response, in part, by supporting oil spill modeling software including GNOME. GNOME calculates the possible trajectory spilled oil might follow based on the ocean currents, the wind conditions, and the type of weathering expected. GNOME can be used to explore oil spill scenarios or operationally to estimate oil spill trajectories in real time. GNOME is currently undergoing a major revision. One important part of the revision is the integration of ADIOS (Automated Data Inquiry for Oil Spills) – NOAA's oil weathering model - within the GNOME system. Because it is expected that oil spilled oil in the arctic will behave differently, there is a need to gather and analyze available data on oil fate and transport in the arctic and to include that characterization within the GNOME system. A second major revision of the GNOME model is the incorporation of ice conditions. It is known that ice conditions affect the behavior of spilled oil, and GNOME developers are still exploring ways to best incorporate available ice data.

In order to facilitate the use of GNOME, NOAA has developed location files which are pre-packaged files containing data on tides and currents for particular locations. There is, for example, a location file for the arctic region. These location files are used for planning and drills. For emergency response, NOAA recommends the use of real-time or forecasted data rather than location file data.

The baseline Technology Readiness Level (TRL) of the arctic aspects of the GNOME model is estimated to be 2.

Purpose/Objectives

The objective of the proposed research is to improve oil spill modeling and planning in the arctic by providing higher resolution ocean current and sea ice data than is currently available and to provide guidance on incorporating the sea ice data within the GNOME modeling framework. A second objective is to gather and analyze available data on oil spill fate and transport processes and to make recommendations to NOAA on how to incorporate that data within GNOME.

Benefits/relevance to DHS
DHS and the Coast Guard will benefit from having an arctic GNOME model for operational oil spill response work and for planning and training.

Student Involvement
The project will involve a postdoctoral researcher as well as a graduate civil engineering research assistant.

Methodology
In the parallel project on ocean/sea ice modeling, the Univ. of Washington will develop high-resolution ocean/sea ice forecasts. Using that data, we will generate the required input files for the GNOME model. These files are referred to as the "Diagnostic Save Files" (or location files) when the GNOME model is used for training or drills. They include data on currents and winds in the project area. UAA will develop GNOME oil spill models for various scenarios with the high-resolution "Diagnostic Save Files" and with conventional normal-resolution files in order to demonstrate the improved performance with the high resolution forcing.

UAA will assist with the incorporation of sea ice data within the GNOME model system. The UW ocean/sea ice modeling effort will generate high resolution data on sea ice concentration, sea ice thickness, and ice floe size distribution. Each of these variables will be space and time dependent. NOAA stakeholder Glen Watabayashi has requested guidance on how to incorporate ice data within the GNOME system.

A considerable amount of research has been done on the fate and transport of oil in the arctic. For example, Shell Oil Company has conducted (or sponsored) research to study the weathering, bio-degradation, and dispersion of oil in arctic settings. UAA will gather and analyze the available data, and we will make recommendations to NOAA on how to account for these processes within an arctic GNOME model. UAA will also identify and report on data gaps.

The work to develop Arctic oil spill modeling expertise (i.e. to develop an arctic GNOME model) is directly relevant to the Lower 48 including the Great Lakes area and other areas with a significant ice presence. This project will contribute to the development of algorithms (within GNOME) for simulating the trajectory of oil in ice covered seas. Once the GNOME model has been revised to represent ice conditions, it will be available for operational and training work in the Great Lakes area and other areas with a significant ice presence.

Key Stakeholder Engagement
Mr. Kurt Hansen and Mr. Richard I Hansen from the USCG R&D Center, Mr. James Robinson and Mr. Mark Everett (US Coast Guard, 17th Coast Guard District), and Glen Watabayashi (NOAA Office of Response and Restoration).

US MDA Challenges addressed: 4, 8, 16.

Milestones and Schedule

1. Completed review of studies of oil fate and transport in the arctic. Provide guidance to NOAA on how to incorporate oil weathering, bio-degradation, dispersion, etc. within the arctic GNOME

model. Identify gaps in knowledge. Also provide guidance to NOAA Office of Response Restoration on how to incorporate ice conditions within GNOME. Years 1 and 2.
2. Completed development of the “Diagnostic Save Files” (or location files) using the high-resolution ocean currents and sea ice conditions generated from the Univ. of Washington ocean/sea ice modeling effort. Year 2.
3. Perform successful runs of GNOME model using the high resolution Diagnostic Save Files and compare output with that generated with conventional Diagnostic Save Files. Year 2.
4. Integration of model data into the IISOS. Year 2.

Metrics

1. Number of reviews of studies on oil fate and transport in the arctic; incorporation of arctic oil fate and transport data within GNOME. Range: 10 studies reviewed to 30 studies reviewed.
2. Level of improvement in resolution of GNOME model relative to conventional GNOME model. Resolution will go from 4 km to a target of 2 km.

Outcomes/output

1. Review of studies on oil fate and transport in the arctic/incorporation of arctic oil fate and transport data and ice data within arctic GNOME. The target TRL is 5.
2. Create “Diagnostic Save Files” or location files for the GNOME model using high resolution output from Univ. of Washington’s high resolution ocean and sea ice model/Running of GNOME with high resolution “Diagnostic Save Files” or location files. The target TRL is 5.

VII.1.d PROJECT: Real-Time Storm Surge and Coastal Flooding Forecasting for Western Alaska

Principal investigator: Dr. Tom Ravens, UAA

Objective/Purpose
The objective is to provide high-resolution forecasts of storm surge and coastal flooding for vulnerable coastal communities in Western Alaska. The year 1 goal is to develop a model for a 150 km x 200 km section of the Yukon Kuskokwim Delta (YK Delta). The model will be validated using water level observations and perhaps with satellite images of inundation extent. In year 2, the goal is to develop a similar model for the Norton Sound area.

Baseline
The UAA-developed high-resolution surge and coastal inundation models for portions of Western Alaska. However, those models have been used for hindcasting; ours will be high-resolution models for forecasting. The baseline situation represents a TRL of 4.

Benefits/relevance to DHS
The Federal Emergency Management Authority (FEMA) works to “Prepare, Plan, and Mitigate before, during, and after a Disaster.” The first FEMA goal is to reduce the loss of life and property. Some of the most vulnerable people and communities in Alaska are the coastal communities on the West Coast of Alaska. These people are vulnerable because climate change has lead to the disappearance of sea ice, which, in the past, had buffered them from fall storms. They are also vulnerable because the lack of an extensive road network limits the evacuation options available to them. The work proposed here will directly assist FEMA by providing high resolution and reliable forecasts of coastal flooding. This data will allow FEMA (and other agencies) to prepare and plan for disasters caused by large coastal storms.

Objectives
The objective of the proposed research is to develop high-resolution surge and flooding forecast model for vulnerable Western Alaska coastal communities. The forecasting model would provide advanced notice of life threatening conditions in these remote communities. It will build on existing model expertise and model products. The goal is demonstrate the project in the Yukon Kuskokwim Delta region in year 1 and to expand the project to the Norton Sound area in year 2.

Student involvement
The project will involve an undergraduate computer science research assistant and a graduate civil engineering research assistant. The two will work together to transform the existing hind-casting model into an operational forecasting model.

Methodology
UAA has developed a high-resolution surge and flooding model using Delft3D software. It is currently being used to hindcast historic storms. The model is a “fine scale” model and it is forced on its ocean boundary using output from a “course grid” ADCIRC model developed by the US Army Corps of Engineers. For DHS, the model will be adjusted allowing it to be run in real time to forecast conditions up to 94 hours into the future. For the real-time forecast model, ocean boundary forcing data will be provided by ET-SURGE (Extra-Tropical Surge model).

The ET-SURGE model runs operationally on National Centers for Environmental Protection (NCEP)’s central computing system four times daily and forecasting as much as 96 hours into the future producing numerical storm surge guidance for extra-tropical systems. The model is forced by real time output of winds and pressures from the NCEP Global Forecast System. Currently, ET-SURGE model does not account for tides in its internal computations. So, we will manually add tides to the water levels provided by ET-SURGE. In year 1, UAA will make the existing YK Delta surge and flooding model operational. In year 2, UAA will develop a new operational surge and flooding model for the Norton Sound area. Model output will be validated using existing and new water level gages.

Key Stakeholders
Mr. Mark Everett (US Coast Guard, 17th Coast Guard District), Mr. Robert Forgit, Federal Emergency Management Agency, U.S. Department of Homeland Security, Alaska Region. Mr. Kenneth Murphy, Regional Administrator, Region X, Federal Emergency Management Agency, U.S. Department of Homeland Security. Aimee Fish, NOAA National Weather Service (NWS) - Alaska Region Headquarters Decision Support, National Weather Service, Alaska; Decision Support and Societal Impacts.

US MDA Challenges addressed: 4, 8, 16.

Milestones
1. Completed code for real-time collection of ocean boundary forcing data for YK Delta model.
2. Completed code for operation of the “fine scale” surge and flood model in real time and in forecast mode (for YK Delta).
3. Completed assessment of the model by comparing modeled and observed water level.
4. Completed integration of model data into the DHS Center for Maritime Research (system of system) control center.
5. Push model data out to stakeholders including FEMA and NWS.
6. Completed reproduction of the above milestones for Norton Sound model.
7. Integration of model data into the IISOS for preparation and response by stakeholders.

Schedule

Year 1 (11/1/14 – 6/30/15):

1. Operational surge and flooding model for YK Delta.
2. Preliminary work for the development of Norton Sound model such as bathymetric and topographic data collection.

Year 2 (7/1/15 – 6/30/16):

1. Assessment of surge and flooding model for YK Delta.
2. Integration of model data into the ADAC system of systems.
3. Conveyance of model data to stakeholders.
4. The above steps are performed for Norton Sound.

Metrics

1. Accuracy of surge and flooding forecasts relative to measured data. Surge calculations currently have errors in the range of 0.5 to 1.0 m. The target error is 0.25 m to 0.5 m.
2. Number of months (or storms) for which YK Delta surge and flooding model is operational in year 2. The number of operational months will range from 12 months (meaning the model was operational for year 2) to 0 months (meaning we did not succeed in making the model operational).
3. Number of months (or storms) for which Norton Sound surge and flooding model is operational. The range of operational months will range from 0 (meaning we did not manage to get the model operational) to 6 months (meaning the model was operational for 6 months).

Outcomes, Output and TRLs

1. Development of an operational storm surge and coastal flooding model for the YK Delta/real-time forecasts of surge and flooding in the YK Delta area. Metric 2. Achieving output 1 is equivalent to reaching a TRL of 7.
2. Comparison of measured and calculated water levels/assessment of the model performance. Metric 1. Achieving output 1 is equivalent to reaching a TRL of 8.
3. Development of an operational storm surge and coastal flooding model for the Norton Sound/real-time forecasts of surge and flooding in the Norton Sound area. Metric 3. Achieving output 1 is equivalent to reaching a TRL of 8.

VII.1.e PROJECT: Identifying, tracking and communicating sea-ice hazards in an integrated framework.

Principal investigator: Dr. Andrew Mahoney, Geophysical Institute, University of Alaska Fairbanks

Baseline

Currently, sea-ice hazards are evaluated based on available remote sensing data and ice charts, both of which have been shown to lack the temporal and spatial resolution to identify and track major sea-ice hazards at the tactical and operational level. Past work by the investigator and industry partners has focused on the development of hardware and software solutions to extract relevant information about ice hazards from marine radar and other sensors available to or in use on USCG vessels and in coastal settings. Now, these tools need to integrate into broader situational or maritime domain awareness contexts, connect to stakeholder decision-support frameworks, and tie into ice-ocean models relevant for emergency/spill response.

Objective/Purpose

Increasing ship traffic, exploration and development of offshore hydrocarbon resources, as well as climate change related threats to coastal and marine infrastructure have greatly increased threats to environmental security in the maritime Arctic. To minimize risks, hazards need to be identified and tracked. Also, coordination and deployment of assets during emergency response, including the involvement of local first responders in a remote and challenging region is necessary.

A framework at the local scale to identify, track and communicate key environmental hazards in ice-covered extreme maritime environments to enhance and inform MDA and emergency response is needed. This project has three objectives to address this problem: (1) Develop a framework to identify and track major environmental hazards in ice-covered extreme environments, with a focus on the coastal zone and offshore assets relevant in the context of maritime activities and hydrocarbon resource development; (2) Based on findings of goal (1) and stakeholder input, develop and/or modify existing hardware and software for an integrated system of ice-based sensors, coastal radar and satellite remote sensing (provided through contractual service by MDA Corporation) to identify and track high-priority ice-associated hazards; and (3) Explore viable approaches in synthesizing resulting hazard-relevant data streams and communicating relevant information products to response/enforcement agencies and stakeholders. We will focus a single key element in objective 1 and 3.

Benefits/Relevance to DHS

Based on input from USCG D17, review of USCG Arctic Information Needs workshop report, and published guidance from USCG Research & Development Center (RDC), the information products and the framework of a North Slope/Barrow ADAC Testbed meet urgent information needs arising from increases in maritime and offshore resource exploration activities. The proposed work addresses several of the 20 US MDA challenges identified by the USCG as well as USCG/DHS MDA mission elements. The proposed work also addresses established information needs within the broader emergency and spill response community, including entities such as NOAA's Office of Response and Restoration (ORR) with a mission to support USCG/DHS with respect to spill response. Moreover, interfacing observing system infrastructure with local and regional first responders directly addresses the needs of DHS' "Responders of the Future" concept identified as a top challenge for the next decade.

Key Stakeholders

USCG District 17: Rob Hynes, James Robinson; USCG R & D Center: Rich Hansen, Bert Macesker; NOAA Office of Response and Restoration: Amy Merten (Chief, Spatial Data Branch/Assessment and Restoration Division); National Weather Service Anchorage Ice Desk: James Nelson, NOAA-NWS Regional Scientist; Rebecca Legatt Heim (Ice Forecaster); Eskimo Walrus Commission: Vera Kingeekuk Metcalf (Executive Director); Eugene Brower (President); Alaska Clean Seas: Tony Parkin (Chair - Research & Development).

US MDA Challenges addressed: 4, 8, 16.

Objectives

(1) Generate an ice hazards demonstration product that directly feeds into USCG and NOAA ERMA MDA and response management tools.
(2) Generate an ice mass-budget/velocity/deformation data product for validation/adaptation of storm surge and ice-ocean modeling (T. Ravens/J. Zhang) and that can be analyzed jointly with coastal HF radar data (T. Weingartner).
(3) Evaluate the potential of a combination of high-precision GPS, coastal radar and satellite remote sensing data in tracking ice hazards and detecting ice threats to coastal and offshore infrastructure.
(4) Develop a conceptual framework for a North Slope/Barrow ADAC testbed for collaborative testing, validation and tactics planning of ADAC program elements relevant to Arctic coastal and offshore environments, including the integration of field-based and remote sensing data for tracking of ice deformation and hazards.

Methodology
Building on the ice radar hardware and software developments for Center for Island Maritime and Extreme Environment (CIMES) project, a geolocation and conversion algorithm will be developed and implemented for generation of ice velocity vector data in near-realtime, in USCG/ERMA compatible format (kml and shape files for ArcGIS). Data for model ingestion/intercomparison will be generated through averaging and potentially resampling to match the model grid. Ingestion of data from in/sub-ice sensors at Barrow testbed will require deployment of dedicated sensor and calibration to derive sea-level benchmarks. Using COTS DGPS receivers we will evaluate whether they have required precision to detect small-scale deformation events indicative of ice instability and potential threats to infrastructure. This work will also be relevant for deployment on drifting ice at higher ice velocities. Coastal radar and synthetic aperture radar data will be analyzed to provide spatial context for these measurements at the ADAC testbed.

Milestones
1. Completion of vector product for ice velocity field in format and delivery mode that conforms with USCG and NOAA ERMA needs (March 2015). Multi-parameter suite of products as vector and raster data available in May 2016. Baseline TRL-4, target TRL-6.
2. Capabilities to produce mean velocity and divergence/convergence fields compatible with ADAC model architecture and coastal HF radar data. (February 2015). Full time series from Barrow site processed by January 2016. Baseline TRL-4, target TRL-6.
3. White paper outlining North Slope/Barrow ADAC testbed, discussing relevant observing system resources, logistics support options, ADAC testbed elements and activities (December 2015). Baseline TRL-1, target TRL-2.
4. Identify and review suitable DGPS hardware for use in harsh Arctic sea-ice environment and compatibility with observing system infrastructure to detect small-scale deformation as threat precursor (April 2016). Baseline TRL-2, target TRL-5.

Technology Readiness Levels (TRL)
The baseline TRL for this project are 4, 4, 1 and 2, respectively for Milestones 1-4, with target TRLs 6, 6, 2, and 5.

Metrics
1. Ice vector product: Number of hits for vector product (velocity in the east and north directions) through data portal. The number of hits will range from 0 hits to 100 hits/ice season; we will monitor website hits during the course of the performance period, and anticipate an increase from current values of 0 to values around 20 during ice season 1 in conjunction with timing of USCG seasonal activities and information needs; we will adapt the product and dissemination approach to achieve >50 hits for ice season 2.
2. Mean ice velocity fields for model validation: Degree of overlap with model grid cells and validation time periods of interest. At the outset of the project there is no overlap because of lack of a high-resolution grid for the forecast model for the region. We anticipate an overlap of <25% (with <10 days of overlap in time) after the first version of the grid has been set up (year 1) and will begin to work towards overlap >75% (with >100 days overlap in time; both being constrained by coastal bathymetry and model resolution) for year 2 of the project.
3. North Slope/Barrow testbed: Metric combines the Number of co-authors on testbed paper (>4), and number of pages (>10), and number of downloads/requests (>10) of the final product. The metric ranges from 0 (present state with no white paper available) to 50.
4. DGPS tracking: Number of days of DGPS receivers operational at Barrow testbed; precision in horizontal and vertical components for location and strain. The number of days of DGPS receivers being operational will range from 10 days to 250 days. We anticipate that for the first field test (Year 2) prior to development of a robust power supply suitable for the harsh

deployment environment, we may be able to collect 20 days' worth of data. Subsequent work will seek to raise this number to the full duration of the ice season. The range for horizontal and vertical components for location will be 0 m to 10 m. The range for horizontal and vertical components for strain will be 0 to 10%. This metric depends on the suitability of the testbed environment at Barrow and the precision of the DGPS array. While remote sensing data suggest that both horizontal and vertical dislocation and resulting strain should exceed a few cm (i.e. be detectable) the first field test, will have to demonstrate that. Subsequent work, guided by feedback from stakeholders, will seek to improve this incrementally.

Outcomes/output

1. Ice vector product: MDA and response efforts by USCG D17 and NOAA ERMA can draw on research products that address information needs on-site and for remote tracking in cases of spill response and identification of potential environmental hazards. Output from this effort will guide development of operational products by federal agencies/private sector by evaluating the feasibility and utility and specifying processing steps for relevant data products. The usage statistics gathered through the product website and direct interaction will help qualify and improve outcomes.
2. Mean velocity fields for model validation: Emergency/spill response modeling and observing components of ADAC are fully aligned with respect to forcing and validation data, thereby supporting development of a modeling system and corresponding tools for USCG and other first responders to draw on in case of emergency or to increase MDA. Tracking the relevant metrics will help ensure that the data pool available for validation of the model is sufficiently large to capture complex ice motion patterns in potential spill response areas.
3. North Slope/Barrow ADAC Testbed: Build leadership role in leveraging existing observing and logistics resources to create a framework for hard/software, sensor and system evaluation and operational testing in a representative Arctic setting that meets needs of USCG and other response organizations.
4. High-precision ice deformation: The suitability for integration of high-precision GPS data in the context of MDA and threat monitoring as well as spill response is evaluated, providing USCG, response agencies, local entities and the private sector with specific guidance on utility and potential next steps in elevating technological readiness. Achieving success in meeting at least 50% of the maximum number of possible acquisition dates for high-precision field data will determine whether the approach is sufficiently reliable for operational use.

VII.1.f PROJECT: Mobile Maritime Domain Awareness using HFR in Remote Settings

Principal investigator: Thomas Weingartner, University of Alaska Fairbanks,
Institute of Marine Science

Abstract:
Increasing marine traffic, expanding interest in offshore exploration and development of hydrocarbon deposits and climate change related threats to coastal and marine infrastructure have greatly increased threats to environmental security in the maritime Arctic. To minimize risks, hazards need to be identified and tracked in the context of Maritime Domain Awareness (MDA). Equally important, MDA needs to anticipate coordination and deployment of assets during emergency response, including the involvement of local first responders in a remote and challenging region.

Our previous DHS-sponsored work focused on developing an autonomous remote power module (RPM) capable of supporting high frequency radars. The RPM, at TRL-9, provides renewable power for the HFR, a satellite communication system, AIS antenna, met sensors and allows real-time transmission and dissemination of these data. The data address MDA issues pertaining to vessel-tracking, oil spill response,

awareness of marine environmental conditions, and search and rescue. The data allow construction of hourly maps of the surface circulation at 6 km resolution and up to 175 km offshore.

Herein we propose to develop and test a smaller, compact RPM (the RPMC), which can be more rapidly and easily deployed than the RPM. The RPMC will be designed with all the power and data communication capabilities of the RPM, but it is intended for shorter (weeks to months) deployments than the RPM (which has an endurance of several months to multi-year).

Baseline:
High Frequency Radars (HFR) provide real-time hourly surface current data at 6 km resolution up to 175 km offshore. The data sets can also be used for vessel-tracking (Statscewich et al., in press). HFR systems are prevalent throughout the conterminous US, where shore-based grid power is easily accessible. Their application along Alaska's coasts has been minimal due primarily to the lack of power. To overcome this problem Statscewich et al. (2011) developed the Remote Power Module (RPM) under prior DHS support. This device, now at TRL-9, provides 500W continuous and allows for the transfer of up to 36 MB/day of data via Hughesnet satellite communication. The RPM provides power, derived from wind and solar primarily, to a battery bank that supports the HFR, satellite communication system, AIS receivers, meteorological sensors, and a data logger. The RPM is modular, flexible, and its components are portable by skiff, snowmachine, and ATV, and so overcome some of the transportation difficulties common to Alaska. The RPM has proved durable, with systems now running for more than 3 years, with only minor parts replaced due to normal wear. The drawback to the RPM is that it is relatively large and takes a team of about four people several days to install. It is thus not as mobile as some MDA scenarios may require. We therefore propose to develop the Remote Power Module Compact (RPMC) that is smaller, has less weight but less redundancy and resilience than the RPM. In particular, our goal is for an RPMC that provides the same power output and communication capability as the RPM, but which can be deployed by helicopter sling loads and require a set-up time of ~1 day. The RPMC is not meant to have the same endurance as the RPM, but will be constructed to provide several weeks to a few months operation in remote settings. We thus regard it as falling in the intermediate time frame for a mobile MDA response. At the one extreme a very fast, but short duration response can be met with a generator set, but this will require non-renewable fuels (and frequent fueling) and manned visits. The RPMC is envisioned as a fast response system that allows for longer endurance, but unmanned, emergency responses. The development of RPMC is at TRL-2.

Benefits/relevance to DHS:
Based on input from USCG D17, review of USCG Arctic Information Needs workshop report and published guidance from USCG Research & Development Center (RDC) the information products and the framework of a North Slope/Barrow ADAC Testbed meet urgent information needs arising from increases in maritime and offshore resource exploration activities. The proposed work addresses several of the 20 US MDA challenges identified by the USCG as well as USCG/DHS MDA mission elements. Moreover, the interfacing of CBON activities with observing system infrastructure directly addresses the needs of DHS' "Responders of the Future" concept identified as one of a handful of top challenges for the next decade. The proposed work also addresses established information needs within the broader emergency and spill response community, including entities such as NOAA's Office of Response and Restoration (ORR) with a mission to support USCG/DHS with respect to spill response. In particular, the RPMC and RPM are designed to power HFR that can be used in oil spill response and planning, search and rescue operations, marine navigation aids, and vessel-tracking.

Key stakeholder end users:
Key stakeholders and end users include the following: (1) USCG District 17 (intelligence and operations, Arctic Shield and offshore exploration activities) and USCG RDC (development of tools for oil spill response, vessel-tracking, search and rescue, marine navigation, (2) NOAA ORR (integration with Arctic ERMA as currently performed with our existing HFR network); National Ice Center and National

Weather Service Anchorage Ice Desk (to assist in ice prediction, particularly during freeze-up); (3) Local response agencies including North Slope Borough Search and Rescue and Public Safety Departments, Village Response Crews, Alaska Clean Seas and other industry stakeholders; (4) Alaska Native hunters and Arctic residents (coastal hazards).

Objectives:

1. In consultation with USCG aviation personnel, develop size and weight guidelines for designing the RPMC so that it can be deployed by helicopter (if necessary). The RPMC will be designed for a high-latitude setting as prevails throughout Alaska.
2. Build and test the RPMC in the arctic in conjunction with HFR operations supported by other entities.
3. Provide HFR current data for evaluation of storm surge and ocean circulation models (T. Ravens) and for joint analysis with ice radar data (H. Eicken).
4. Explore viable approaches for a North Slope/Barrow ADAC testbed that provides a framework for collaborative testing, validation and tactics planning of ADAC program elements relevant to Arctic coastal and offshore environments.

Student involvement:
Undergraduate or graduate students will be involved to assist in the construction of the RPMC.

Methodology:
In order to initiate a rapid response to an event requiring ocean current measurements we will build upon our previous success with the RPM and provide a power plant, data logging and telemetry solution that is capable of being lifted to remote coastal sites via helicopter support. The RPMC concept envisions a total weight within 2-3 sling loads (depending upon aircraft) and setup time is less than 1 day. The system will rely on solar, wind and generator power to charge a small battery bank capable of supporting the radar, data logging and telemetry electronics for a period of up to 3 months. A small shelter will house the battery bank, HFR, telemetry and power distribution electronics. The shelter itself will contain environmental controls to ensure the electronics are kept at optimal temperatures including resistive dump loads in case the wind turbines produce more power than the battery bank can accept. The shelter will sit on four adjustable feet to accommodate uneven or soft surfaces. Once the system is built in Fairbanks, it will be tested at an arctic coastal location in Alaska. The testing could include a test airlift by USCG personnel with their helicopters (alternatively, a USCG helicopter test could be conducted in Fairbanks or Anchorage, before the RPMC is shipped to the Arctic). After successful RPMC testing has been performed, we will develop a training course on the device. The course will address hardware and software setup, operation and troubleshooting, and data handling for troubleshooting purposes and will be developed in consultation with, and geared toward, USCG personnel if so desired.

Milestones:
Year 1: There are insufficient funds to achieve any useful results, so no funding is requested.
Year 2: Develop RPMC design in consultation with USCG aviation experts. Begin acquisition of materials and construction of the RPMC and complete if there is sufficient funding.

Metrics:
Year 1: None
Year 2: Depends upon level of funding, but we envision:

1. Design completed and approved by USCG aviation personnel (Level of completion: 10 - 15%). Note that the design differences between the RPMC and RPM are expected to be small. These will largely entail designing a structure that can be airlifted safely and securely and in accordance with USCG parameters.
2. Acquisition of materials/equipment and preliminary construction of the RPMC (level of completion 15 – 50%).

3. Complete RPMC construction and component testing so that the device is ready for field testing (level of completion: 50 - 100%). Note that the components are tested individually once they arrive from the manufacturer. Hence the level of completion will also be 50 – 100%.
4. Depending upon funding level and opportunity: testing may include helicopter sling load tests in Fairbanks and will depend upon USCG helicopter availability.

Outcomes/output and TRLs:

1) The RPMC is at TRL-2 now. The target levels are:
    a. TRL-4 by the end of year 2
    b. TRL-9 by the end of Year 3 (assuming that metrics 1-4 are completed in Year 2) or Year 4 (if the RPM-C metrics cannot be attained in Year 2, but carryover to Year 3).
2) Existing projects (funded by other agencies) will provide processed HFR data as requested for emergency/spill response modeling and observing components of ADAC that lead to situational awareness. We will provide these data to the extent possible assuming that the ADAC requests entail no additional costs in acquisition and/or processing. This is not anticipated at this time.

VII.1.g PROJECT: Monitoring intentional and unintentional catastrophic events: detecting oil spills through measurements of the C and H_2O isotope geochemistry in winds

Principal investigator: Dr. Jeff Welker, Professor and Fulbright Distinguished US Arctic Chair-Norway, Department of Biological Sciences, UAA

Abstract

Winds of maritime systems will be continuously monitored for their speeds, directions and their carbon (C) and H_2O isotope properties as a means of detecting extreme events such as oil spills and sea ice expansion and contraction against a natural background of atmospheric chemistry. The goal is to provide real-time, continuous data of wind isotope chemistry, its directions and the spatial extent to which they reflect the surrounding maritime and coastal zones, and to alert USGC to intentional and unintentional events. We will initially establish one monitoring station at the Port of Anchorage in Cook Inlet and in year 2 a second station in Nome, Alaska, on the Bering Sea Coast.

Monitoring petroleum spills in the environment using C isotopes is an emerging approach. It builds on the established approach to measure the background ^{13}C traits of the atmosphere in order to establish that fossil fuel emissions are driving the changes to CO_2 in the atmosphere. The novelty of the proposed program is to measure the huge plumes of depleted ^{13}C associated with spills as a tool for maritime monitoring. It is expected, but unconfirmed, that these are weekly events in large areas surrounding the Ports of Anchorage and Nome. The proposed method will allow the detection of such events not just in the ports but also in large and remote areas.

We will use two laser-based Picarro isotope devices, one for $^{13}C/^{12}C$ ratios in CO_2 for oil detection and will collect additional environmental data including $^{18}O/^{16}O$, $^{2}H/^{1}H$ ratios in water vapor for sea ice detection that will be operated in parallel in combination with a suite of micrometeorological devices for air temperature, wind speed, wind direction, and relative humidity. The simultaneous monitoring of CO_2 and its C isotopes will alert us of oil spill vapors from a specific direction as oil vapors have a particular C isotope signature that is drastically different from ambient values. This will allow for the detection of remote oil spills and monitoring dynamics of the oil spills and sources. Such information will be used in the oil spill models in Theme 2 Task 5. As part of our first year efforts, we will install a tower in the Port of Anchorage. To improve the predictive power of this approach these measurements will be combined with near ground level measurements collected by the CBONs and in year 3 with canopy level measurements using UAV-mounted miniaturized laser spectrometers. These ground and canopy

level measurements will provide additional information needed to account for the sources and mixing of water vapor and CO_2 in the atmosphere with surface water and land based ecosystems.

Baseline
Our baseline technology readiness is at level 5, as we will be using existing, state-of-the-art devices that will require establishment and operations at new location(s). Our research readiness is low at this time, as new data collection has not been undertaken at the field site(s) so it is at level 1. It will be at level 5 by the end of year 1 as data collection and delivery will have been underway for months.

Our baseline is also founded on the fact that the isotope geochemistry of C associated with petroleum products, especially oil, that are hugely different from background air. Thus, oil vapor being transported by wind to shore-based stations can be detected in real time using new laser-based technology. Simultaneously, water vapor that is sublimated off of sea ice into the surrounding atmosphere compared to water vapor from partially ice free water are isotopically distinct and can be measured continuously in real time with new laser based technology. Thus, water vapor being transported in winds across open as opposed to ice-covered toward shore-based stations can inform us about the sea ice conditions across remote seascapes. Combining real-time wind isotope chemistry with wind direction and wind speed in a back-trajectory model allows one to delineate long-distance transport paths and regions of oil spills and regions of different sea ice conditions.

Benefits/relevance to DHS
Station-based measurements of atmospheric C and water isotopes will provide the information necessary to detect petroleum products in air from ship emissions and from oil spills and sea ice expansion and contraction against a background of natural variability. Continuous measurements will provide real-time data streams of the ^{13}C of CO_2 and the ^{18}O and ^{2}H of H_2O water vapor, providing the basis from which to detect breaches of maritime security. These real-time data streams will be accompanied by a compilation of regional climate and weather in collaboration with NOAA, AOOS, and NWS.

Key stakeholder
The US Coast Guard, the Port Authority of Anchorage, State of Alaska Department of Conservation (DEC), the scientific community including bio-geochemists, hydrologists and ecosystem ecologists, and climate and storm-track modelers. The USCG and the Port of Anchorage can use this data and information to assess the intensity of sea ice in Cook Inlet and detect anomalous oil, diesel or petroleum spill events. In addition they will be able to ascertain emerging changes in ice extent and the degree to which the sea ice is either degrading or expanding. The DEC can use this data as a means of developing correlations between sea ice extent and marine mammal distribution and initiate emergency response protocols in the event of a detected large-scale oil, diesel or petroleum spill/event. Sea ice models developed in this Theme: Projects II.1.b and II.1.e will be able to incorporate intensity measurements that occur in real-time into their forecasting and model calibration for the Cook Inlet.

US MDA Challenges addressed: 4, 8,16.

Objectives
Continuously measure the chemistry of the maritime atmosphere as a means of detecting and sourcing ship emissions, oil spills and to characterize sea ice conditions at the Port of Anchorage and along the Bering Sea coast. Provide real-time data on Cook Inlet atmospheric properties that are linked with other climate data sets being provided by AOOS, NOAA and NWS. Develop pilot testing of UAVs as carriers of C-based measuring devices for spatial analysis of oil contamination.

Student involvement
Undergraduates, Research Technician (MS graduate from UAA) and a Postdoctoral Fellow.

Methodology
Placed-based stations outfitted with an $^{18}O/^{2}H$ water isotope analyzer at the Port of Anchorage, running continuously in the Headquarter Building in conjunction with the NOAA micrometeorological station. Collate and integrate COE station data with AOOS, NOAA and NWS climate stations in Cook Inlet. (FYI: in year one due to budget constraints, the ^{13}C isotope analyzer will not be operational at the Port of Anchorage; it will be operational in year 2).

Milestones Year 1
1. Instruments ordered;
2. Station siting secured with the Port of Anchorage;
3. Winterized housing for the devices secured, power delivery secured;
4. Station installation, instruments deployment, instrument calibration;
5. Instruments operational, data streaming to the COE Headquarters.

Milestones Year 2
1. Completed ordering of station instruments;
2. Completed winterized housing for the devices secured, power delivery secured;
3. Completed station installation, instruments deployment, and instrument calibration;
4. Completed bringing instruments into operational states and data streaming to the COE Headquarters;
5. Completed initial testing in Port of ANC area and fitting a UAV with a C-sensing device;
6. Completed design for portable of isotope devices to be loaded on UAVs.
7. Integration of model data into the IISOS.

Metrics Year 1
1. Levels of compliance with instruments calibration specifications. The target level of compliance of the instruments will range from 98 to 100%. This will allow us to establish the ranges (standard plus/minus deviation) of normal concentrations for the observation area. For water vapor isotopes the standard deviation for standards will be less than 0.5 per mil for $\delta^{18}O$ and 2 per mil for $\delta\,^{2}H$.
2. Daily coefficient of variation of the measurements. The daily coefficient of variation will range from 50 to 100%. The goal will be to assign this variation to fluctuations in wind trajectory, sea ice conditions and moisture sources. By assigning the variation to specific cardinal direction (0-360^{o}) we can then ascertain whether the changes in the water isotope properties are associated with changes in ocean conditions, or changes in land-based properties. We will develop an algorithm that calibrates the water vapor isotope values with sea ice extent (satellite derived) during periods in which the plumes of water vapor are coming right off the ocean. These isotope-sea ice extent calibrations will then allow us to continuously, in real-time, monitor sea ice (via the water vapor isotopes) as opposed to the once a day sea ice estimate retrieved from the satellites.
3. Volume of data delivered to the COE Headquarters. 10 MB/day. We will measure our data volume and we expect that this will double as our instrument packages grow at the Port of Anchorage and in Nome.
4. Variance in sea ice extent detected will be less than 30% compared to MODIS Aqua images for the same periods. We anticipate that the variance will be less than 20% in year 2.

Metrics Year 2
1. Levels of compliance with instruments calibration specifications. The level of compliance of the instruments will range from 98 to 100%. For water vapor isotopes the standard deviation for

standards will be less than 0.5 per mil for $\delta^{18}O$ and 2 per mil for $\delta^{2}H$ and for $\delta^{13}C$ in CO_2 it will be less than 1 per mill.

2. Daily coefficient of variation of the measurements. The daily coefficient of variation will range from 50 to 100%. The goal will be to assign this variation to fluctuations in wind trajectory, sea ice conditions, moisture sources, petroleum sources and emissions.
3. Accuracy in detection of ship emissions will exceed 75% compared to know tracking routes and will exceed 80% in year 2.
4. Volume of data delivered to the COE Headquarters. 30 MB/day and will increase as our instrument packages at the two sites increase. We will monitor data delivery and verify our volume.
5. Variance in sea ice extent detected will be less than 30% compared to MODIS Aqua images for the same periods. We anticipate that ship-based losses of petroleum products and emissions will be detectable within the active air-shed within 1-10 miles, depending on wind speed and direction.

Schedule
Year 1
1 December 2015-equipment ordered and staff hired, 10 December-site finalized with Port Authority, 10 January 2015 -$^{18}O/^{2}H$ system bench tested at UAA, 25 January tower system erected, 1 February isotope system operational, 15 February-data streaming from the Port of Anchorage to the COE. 1 March-first data synthesis.

Year 2
1 May 1-equipment ordered, 1 July instruments set up, 1 August instruments operational, 1 September-data streaming to COE Headquarters, 1 October first data synthesis. 1 July UAV on site at Port of Anchorage, 1-15 July UAV test flights.

Outcomes/output
Year 1
Background daily, weekly and monthly atmospheric properties of water isotopes will be punctuated by variance in sea ice cover variance in Cook Inlet and will be compared to satellite images of Cook Inlet. Continuous real-time water isotope values will be visualized in the COE Headquarters and discrepancies between background and extreme events will result in immediate notification of the USCG and the Port Authority. (Year 1 metrics 1, 2, 3, and 4.)

Year 2
Background daily, weekly and monthly atmospheric properties of carbon and water isotopes will be punctuated by vessel traffic and sea ice cover variance along the Bering Sea coast and Cook Inlet. Continuous real-time C and water isotope values will be visualized in the COE Headquarters and discrepancies between background and extreme events will result in immediate notification of the USCG. Year 2 metrics 1, 2, 3, 4, and 5.

VII.2 THEME 2 MARITIME TECHNOLOGY

Theme Lead: Dr. Kenrick Mock, Associate Dean, College of Engineering, UAA
Email: kjmock@uaa.alaska.edu

VII.2.a Integrated Intelligent System of Systems

Principal Investigator: Dr. Robert Finkelstein, RTI.

Baseline

In this project we will use the 4D/RCS reference architecture to develop a software-based Integrated Intelligent System of Systems (IISoS). The IISoS will input data from multiple sensors, intelligently process the data, and make actions or notifications to manage potential incidents. The IISoS will be linked to the Arctic Maritime Situational Awareness and Response Support (MSARS) Command Center where information will ultimately be aggregated and visualized for decision-making.

The 4D/RCS was originally developed by the Intelligent Systems Division of NIST and is a reference model architecture for intelligent systems. (The “4D” represents the four dimensions of space and time, while the “RCS” is an abbreviation for Real-time Control System.) It has been demonstrated and proven in multiple of applications and testbeds. While computer code exists for various applications, we will develop the software to be used within the 4D/RCS framework in which sensors, sensor processing, databases, computer models. Machine controls will be linked and operated such that the system behaves as if it were intelligent. Most of the hardware components of the IISoS, such as sensors, computers, robotic vehicles, and communications devices, already exist, either as COTS products or operational prototypes. The software for MSARS does not yet exist.

The 4D/RCS architecture has been demonstrated successfully over the years for many applications, including: industrial robotics; computer-integrated manufacturing; open-architecture controllers for machine tools; multiple autonomous undersea vehicles; experimental controllers for nuclear submarines; space station telerobotic systems; telerobotics for aircraft maintenance; postal service stamp distribution and general mail facilities; controllers for laser, plasma, and water jet cutting machines; vision-guided highway vehicles; automated mining machinery; robotic cranes; and autonomous unmanned ground vehicles. Thus while the architecture has not yet been developed and demonstrated to serve as basis of a Command Center, like the MSARS, there is sufficient knowledge from prior applications to provide a foundation for the Command Center.

The baseline and target Technology Readiness Levels (TRLs) for the IISoS and its major subsystems for Years 1 and 2 are given in **Table 1**. The robotic (unmanned) vehicle systems are all demonstrable systems, ranging from TRL 5 to 8, and the satellites fully operational, i.e., TRL 9. However, in the context of the IISoS, they are untested components of the IISoS, so the TRLs for the robotic platforms and the sensor and communications networks have TRLs lower than they might be as stand-alone entities. Also, some of the subsystems will not be incorporated into the IISoS during Years 1 and 2 (e.g., high altitude UAV, USV, and UUV), in which cases their TRLs will not change (with respect to the IISoS) during Years 1 and 2. The 4D/RCS has been demonstrated successfully in the past (TRL 6-7), but not for the IISoS application, so its TRL is conservatively lowered for the Year 1 baseline. The overall baseline for the IISoS is starting at a concept level (TRL 2) and ending in Year 1 with a target level of TRL 3, although a part of it (but not all) will be verified, validated, and tested (VVT) in a relevant environment (TRL 5). In Year 2, the target level for the IISoS is TRL 4.

TABLE 1: BASELINE AND TARGET TRLs FOR YEARS 1 AND 2

	YEAR 1		**YEAR 2**	
Component	**Baseline TRL**	**Target TRL**	**Baseline TRL**	**Target TRL**
Satellite	7	7	7	8
High Alt. UAV	5	5	5	5
Low Alt. UAV	6	7	7	8

UGV	6	6	6	7
USV	6	6	6	6
UUV	6	6	6	6
CBON	5	5	5	6
Sensor Network	4	5	5	6
Comm. Network	4	5	5	6
4D/RCS	3	4	4	5
IISoS	2	3	3	4

Objective/Purpose

The primary research question is: can an IISoS, with an MSARS Command Center, be successfully designed, developed, tested, and demonstrated as a timely OODA Loop for first responders and decision makers in response to natural and adversarial Arctic maritime threats? A secondary research question is: can the IISoS can be synthesized from varied robotic platforms (i.e., satellites, UAVs, UGVs, USVs, and UUVs) from diverse vendors and new software code written, tested, and implemented to integrate the components of the IISoS within the control system architecture?

The major objective for this project is to adapt the 4D/RCS reference architecture to the Arctic Maritime domain serve as the controlling core of the IISoS. To date, the 4D/RCS has primarily been used as a control system for land-based robots. We will use the same architecture but modify it to operate as a maritime information and action architecture. It could also be used in the future to control the robotic vehicle subsystems in the IISoS multi-level array of unmanned vehicles covering space, air, land and sea. The lessons learned from this program will impact the nation's safety, economy, and environment, including new technology suitable for the Department of Homeland Security. This is a new application of the 4D/RCS, and one purpose of the research is to advance the state of the technology for autonomous intelligent machines.

The goals comprising the objective will be to: integrate the components into a coherent whole; configure the 4D/RCS for the MSARS application; create and implement new software for the 4D/RCS; codify knowledge to make inferences in the maritime domain; verify, validate, and test the IISoS in the context of suitable scenarios. The goal for the final system is to intelligently integrate remote sensors, human intelligence, databases, unmanned autonomous vehicles, and communications devices to effect decision making.

An integral part of our research will be to investigate and to understand USCG command centers and how they operate including their information fusion, analytics, and visualization needs and various capabilities of the USCG. In particular, by the end of the first year Dr. Finkelstein and the team will conduct a detailed study to understand how coast guard command centers operate. The study will begin by working closely with USCG District 17 on the District's commitment to build an Arctic Data Fusion Center (ADFC). This will include visits to their facility as needed. By the end of the first year the team will produce a plan to design and implement the ADFC. The team will be the working closely with LTCMDR McGoey and CAPT Deer from USCG District 17. In the following years we will extend the approach to work with the command centers for other DHS components including Customs and Border Protection.

The system of systems is a high-priority technology for the UAA COE. Therefore, a major purpose of this project is to deliver, each year, a demonstration that is commensurate with available resources and past work, satisfies the DHS/Coast Guard missions, and features the IISoS OODA Loop.

Methodology

For Years 1 and 2 we will employ both qualitative and quantitative methods in our R&D of the IISoS and 4D/RCS. For example, creating a narrative for the demonstration scenario is qualitative, while evaluating the success of the demonstration ensuing from the scenario is largely quantitative. Our tasks include:

- Educate internal stakeholders about the 4D/RCS architectural framework for the IISoS and the MSARS. If desired, arrange meetings at the Intelligent Systems Division of National Institute for Standards and Technology (NIST) for Dr. Mock and UAA software developers to discuss the 4D/RCS.
- Develop suitable scenarios for the Year 1 and 2 demonstrations, with the Year 1 demonstration featuring at least one unmanned (robotic) vehicle and Year 2 adding another unmanned vehicle.
- Coordinate with the industry teaming partners who will provide subsystems for the demonstrations on the design, schedule, and implementation of the demonstrations.
- Analyze the prospective sensors and other sources of data for the Year 1 and 2 demonstrations and select the most important and feasible sources. Year 1 sources include inputs from CBONs, UAV, satellite, and prototype sensor networks.
- Design the 4D/RCS architecture for the Years 1 and 2 versions of the IISoS including the modules for sensing, perception, and knowledge representation for world modeling, value judgment, and behavior, suitable to support the demonstrations.
- Design the internal and external communications protocols and bandwidth for the 4D/RCS (i.e., communication between 4D/RCS modules and between the 4D/RCS and data (sensor) sources, and between the 4D/RCS and OODA Loop Act message recipients. The protocols determine the rules that govern who may communicate with whom, and when this communications may occur. In addition, determine how the communication takes place and the content (or data model) for what is communicated.
- Code (program) the 4D/RCS modules to provide a solid foundation and template for UAA programmers (e.g., post-doc graduate students) to expand during the second and subsequent program years. Design and implement the verification, validation, and testing (VVT) of the 4D/RCS.
- Employ the canonical paradigm for systems engineering: throughout the stages of the system development process (including system definition, design, implementation, integration, etc.) employ verification, validation, and testing (VVT) tools and techniques best practices.
- Analyze and suggest additional DHS applications for the technology.
- Write monthly status reports, a year-end report, and presentations as requested.
- Incorporate data fusion methods from HSARPA – Data Analytics Lab.

Stakeholder Engagement
The IISoS is a central component of MSARS and thus has the same external stakeholders, who are identified as Mr. Mark VanHaverbeke, USCG Research and Development Center and Capt. Evans, USCG RDC, in the E2E work plan as well as Captain Deer, CMDR Watson, and LTCMDR McGoey, USCG D17, Mr. Jonathan McEntee, Deputy Director, Borders and Maritime Security Division DHS S&T. The first and second year demonstrations, and the associated scenarios, will be developed in close conjunction with the stakeholders. Consequently, the year-by-year development of the 4D/RCS and the SOS, and their technology, contents, and functions will depend on satisfying the needs and wants of the stakeholders, as then reflected in the demonstrations of the SOS and 4D/RCS. In addition, a collaborative effort with HSARPA, Mr. Stephen Dennis, Big Data and Analytics, to use HSARPA's new data fusion software on the various sensor data received into the IISoS. This will provide new data types for HSARPA to test their systems.

US MDA Challenges addressed: 4, 8, 9, 10, 12, 13, 15, 16.

Metrics and Milestones
The IISoS is a central component of the E2E demonstration for the Years 1 and 2. The initial instantiation of the 4D/RCS will be designed to be sufficient for the first demonstration. It will exhibit the ability of a UAV and the IISoS to implement the features of the OODA Loop and demonstrate the ability of the system to process sensor and human-input data into useful information, which is disseminated to first responders and other key recipients. The Year 2 demonstration will include an additional unmanned vehicle, possibly the USV or UUV, sensors developed, and CBONS. In Year 2, the 4D/RCS will be enlarged to include additional entities, relationships, and behaviors suitable for the Year 2 demonstration.

Major milestones for the Year 1 of the 4D/RCS and IISoS will include:
1. Completion of a scenario and demonstration design to illustrate its capabilities.
2. Design and implementation of the 4D/RCS and its code within the scope of the demonstration scenario.
3. Completion of the VVT for demonstration scenario the 4D/RCS, IISoS, and integration with MSARS.
4. Successful completion of the scenario demonstrations.
5. Documentation for the 4D/RCS (e.g., a user's manual) and IISoS.
6. Establish necessary connections with the portal of USCG in Juneau.
7. Understanding USCG Command Centers and how they operate.
8. Successful incorporation of data fusion methods developed by HSARPA.

Year 2 we will refine and expand the capabilities of the IISoS. Milestones include:
1. Incorporation of additional sensors that includes CBONs, satellite, UAV, Smart-Cam, and other sensor networks.
2. Completion of additional scenario and demonstration design.
3. Knowledge representation and development to act upon additional sensor inputs and their VVT.
4. Successful completion of the new scenario demonstrations.
5. Write and submit project results to peer-reviewed venue.

Metrics and Submetrics Evaluation Method: The Analytic Hierarchy Process (AHP)
The AHP process has been favorably reviewed by the operations research community (as a technique for multivariate decision-making) and has gained popularity in the defense industry for aiding in the evaluation of weapons systems and other applications. For example, we have used it for Department of Defense technology assessments and homeland security critical infrastructure risk avoidance and mitigation. There are more than 600 papers and books describing the theory and diverse applications of the AHP.

As limited human beings with limited brain capacity, we find it difficult to make decisions about complex problems involving conflicting criteria and several alternatives. Our short-term memory can hold only a limited amount of data "chunks" - like a grocery list or a phone number. If we try to compare a number of attributes (such as size, speed, development risk, cost, reliability, etc.) among a number of choices for prospective robotic vehicles all at once in our head, we typically get entangled. Our decisions are less than the best.

Complex systems or problems can be simplified by decomposing them into smaller, comprehensible elements or tasks. Human society has done this for thousands of years with organizations (the bureaucracy) and complex projects (such as building the pyramids or nuclear submarines). The AHP technique enables the decision-maker to transcend mental limitations by restructuring a complex problem in the form of a hierarchy. Each attribute, criterion, or metric (measure of merit) is identified or defined along with sub-metrics in a systemized way and then used, step by step, to evaluate the alternative choices. This ability to structure a complex problem, and then focus attention on individual components, improves decision-making.

The AHP makes it possible to look at the elements of a problem in isolation: one element compared against another with respect to a single criterion. The decision process reduced to its simplest terms - pairwise comparisons. There is never a need to look at more than two things at a time - well within our limited mental capacity. The user just focuses on the basic elements of the problem and the process leads to all of his or her judgments being synthesized into a unified whole in which the alternative solutions are clearly ranked and placed in priority order - from best to worst.

The decision maker's judgments form the basis of the AHP process. Judgments are made about pairs of elements relevant to a criterion or property that they have in common. For example, one might examine the data on two robotic vehicles and note objectively that the first is heavier than the second, uses more fuel per mile than the second, has more payload capacity than the second, or costs more than the second. We can also judge subjectively that the first is less of a development risk than the second. Judgments are derived from multiple pairwise comparisons of alternatives against various criteria (using objective data whenever it is available). The resulting decisions are more objective and rational than they would be otherwise.

The number of criteria considered in a particular decision can be large. For example, robotic vehicles may be compared according to measures of size and weight, payload capacity, sensor requirements, acquisition cost, maintenance cost, range, fuel efficiency, safety, reliability, road speed, cross country speed, and so on. The measures of merit - MOM - may often be categorized as measures of effectiveness (doing the right thing) or measures of efficiency (doing things right). It is futile to pursue the wrong objective even in a highly efficient manner. But pursuing the right objective inefficiently wastes resources, and the objective ultimately may not be achieved. In any case, the AHP makes it easy to organize and simplify complex problems with a large number of criteria.

While it is preferable to use objective data (such as size and cost) in the decision-making process, qualitative factors such as perceptions of risk, aesthetic judgments, psychosocial behavior, and political issues, are difficult to assess solely in terms of objective or physical measurement. However, such seemingly non-measurable factors can be included in the evaluation process. Just as we can distinguish and measure physical quantities, such as meters for length or dollars for cost, we can do the same with our perceptions of qualities. Even objective characteristics may be treated as subjective in the absence of data that would otherwise quantify them. Because we can discriminate subjectively, we can develop relationships among the elements of a problem and to determine which elements have the greatest impact. The AHP can accommodate both quantitative and subjective inputs, and merge them into a single overall measure to determine which alternative solution is the most desirable.

Various researchers have tested the AHP. They determined that its technique of scale measurement works in fields where the units of measurement are already known, such as physics, economics, and other fields where standard measures already exist. In the scaling process, the user expresses the relative importance or preference of one entity over another, with respect to a given criterion, either verbally or numerically. Verbal comparisons can be used for comparing social, psychological, political or other subjective factors, while numerical comparisons can be used for comparing physical, economic or other objective factors.

The underlying mathematical process in the AHP is matrix algebra and solving for Eigenvalues.

One difficulty with the AHP is for the user to be consistent in making pairwise comparisons. Consistency is mathematically a transitive property of preference. It requires that if entity A is preferred to entity B, and entity B is preferred to entity C, then entity A should be preferred to entity C. (If you prefer a Ford to a Chevy, and a Chevy to a Buick, you should prefer a Ford to a Buick). The AHP process calculates a measure of inconsistency. This measure is useful in identifying possible errors in expressing judgments as well as actual inconsistencies in the judgments themselves. However, the usual method does not preclude all inconsistencies in judgments because many decisions must be made in the context of inconsistencies that exist in the real world.

Metrics and Submetrics

The selected metrics and submetrics were evaluated and, in an exercise, were weighted (scored) using the AHP. The alternative IISoS configurations and demonstrations can then be evaluated and compared against the weighted metrics and submetrics.

The three metrics for the IISoS are: Effectiveness, Efficiency, and Cost. Effectiveness measures whether the system does what it is intended to do, while Efficiency measures how well it does it. Cost could be subsumed in Efficiency, but budgets are treated as a separate resource (e.g., from time and materials), so it is treated here as a separate metric. In an example exercise of the AHP, Effectiveness (weighted 0.54) was deemed more important than Efficiency (weighted 0.30) because in an R&D project accomplishing the objectives is generally more important than whether the objectives are accomplished most efficiently with minimum resources (e.g., in least time). Both Effectiveness and Efficiency were deemed more important than Cost (weighted 0.16) because the cost should be within an a priori budgetary constraint and reducing it further is not critical in the R&D process.

Effectiveness was decomposed into submetrics based on the OODA Loop: Observed (the fraction of entities in the scenario demonstration that are correctly observed); Oriented (the fraction of potential threats that the system correctly orients towards; Decided (the fraction of correct decisions with respect to threats); and Acted (the fraction of correct actions taken with respect to threats). Observed (0.39) scored higher than Oriented (0.27) because if a potential threat is not observe in the first place, the OODA Loop cannot deal with it at all. Likewise, Acted (0.14) scored less than Decided (0.20). The inconsistency ratio is 0.05, which is acceptable.

Efficiency was decomposed into submetrics also based on the OODA Loop: Perceive (the time for the IISoS to perceive the potential threat); Configure (the time for the IISoS to configure itself so it is oriented toward the potential threat; Converge (the time it takes the IISoS to converge on the decision that there is a threat; Respond (the time it takes the IISoS to respond to the threat (e.g., propagate information). Reflecting the rationale for the Effectiveness submetrics, Perceive (0.39) was deemed most important, followed by Configure (0.28), Converge (0.19), and Respond (0.14). The inconsistency ratio is 0.05, which is acceptable. The acceptable timing for the OODA Loop will be defined each year, with standards being tightened each year.

Cost was decomposed into submetrics Cost to Develop (which scored 0.61) and Cost to Demonstrate (which scored 0.39). For each year, the cost of the IISoS to be developed (or evolved) and demonstrated in that year was deemed more important the cost of the demonstration of that system, which is more flexible because the demonstration is more flexible than the development of the system. The inconsistency ratio is 0.0 because with only two submetrics there can be no inconsistency.

Table 2 shows the acceptable values of the IISoS OODA metrics (or submetrics), to determine system functional performance, for Years 1 and 2, as measured during the final demonstrations for those years. Annual incremental improvements continue until the end of Year 5: linearly for the effectiveness metrics and non-linearly for the efficiency metrics. The IISoS and its OODA metrics will be managed and evaluated during each year in the VVT process, leading up to the final annual demonstration.

Table 2: Acceptable Values for the IISoS Functional Metrics

OODA METRIC	YEAR 1 GOAL	YEAR 2 GOAL
Observed	0.6	0.7
Oriented	0.6	0.7
Decided	0.7	0.8
Acted	0.7	0.8
Perceived	30 minutes	15 minutes
Configured	20 minutes	10 minutes
Converged	12 minutes	6 minutes
Responded	10 minutes	5 minutes

Key:

Effectiveness

- Observed = Fraction of significant entities in scenario demonstration that the system (IISoS) correctly observes
- Oriented = Fraction of potential threats the system correctly orients toward
- Decided = Fraction correct decisions made by the system with respect to threats
- Acted = Fraction of correct actions taken by the system with respect to threats

Efficiency

- Perceived = Time it takes for the system (IISoS) to perceive potential threats
- Configured = Time it takes or the system to configure itself so it is oriented toward the potential threats
- Converged = Time it takes for the system to converge on the decision that there is a threat
- Responded – Time it takes for the system to respond to the threat (e.g., propagate information to first responders)

Outcomes and Output

The outputs for Years 1 and 2 will be successful demonstrations of the 4D/RCS and the System of Systems. By the end of Year 1 the outcome will be a systems framework that can incorporate multiple input sources, intelligently process the data, and transform the data to actionable information. The Year 2 demonstration will show how the 4D/RCS can expand and evolve, increasing in intelligence and becoming capable of controlling a IISoS growing in size and complexity. The outcome will be an IISoS with an intelligent control system, the 4D/RCS, at its core, able to adapt to other applications and environments (e.g., non-Arctic, land borders, general counter-terrorism, etc.).

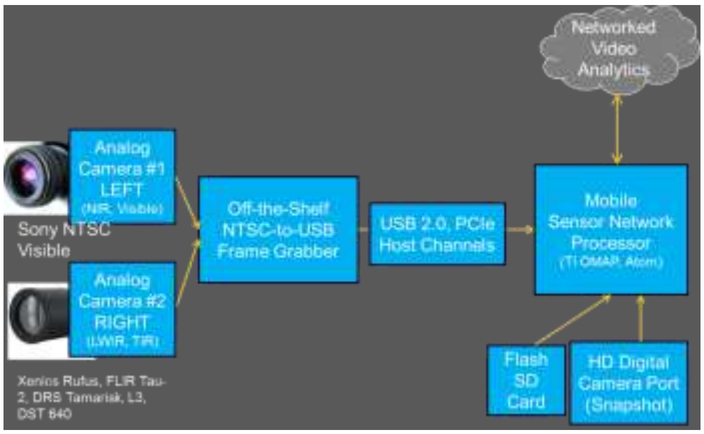
VII.2.b PROJECT: Smart Cam [Computational Photometer]

Principal Investigator: Dr. Kenrick Mock, UAA and Dr. Sam Siewart, Contractor (former UAA professor)

Baseline

The Smart-Cam focus is to develop low power, solar recharging and ad-hoc sensor networking protocols to uplink data with minimal power use and with opportunistic uplink to maritime vessels and UAVs. The system will be designed for deployment on land or vehicles, with design consideration for use in AUVs to assess capability for use to detect oil under sea ice. In this early phase, initially in the Port of Anchorage, key aspects are wireless uplink, battery operation, and power efficiency characterization with the intent to improve future versions and design. The baseline configuration, depicted in Figure 1, can be constructed entirely from off-the-shelf components and uses the OpenCV library, so focus will be on a power baseline, algorithm evaluation for DHS mission directives, and characterization of low-cost off-the-shelf microbolometers combined with visible for multi-spectral applications such as detection of oil, working with other DHS center of excellence partners. A prototype currently exists at TRL-4.

Figure 1: Baseline Smart-Cam Configuration



Objective/Purpose

The goal is to construct a proof-of-concept visible two channel (optional visible + long wave infrared multispectral) camera proof of concept to be tested at the Port of Anchorage starting in summer or fall of 2015 in the follow-on 2015/2016 period of performance. The proof-of-concept will be constructed using all off-the-shelf hardware components and used to form a baseline of comparison for the longer term Computational Photometer ("Smart-Cam") that is a longer term goal of the research, for Arctic operations with drop-in-place multi-spectral and stereo vision cameras as described in Theme 3, Task 2, Topic 3c. From the proof-of-concept it is expected that challenges of long term battery operations, drop-in-place packaging for Arctic environments, and power efficiency and methods to recharge can be better understood for follow-on phases. Furthermore, this will be a proof of the integrated software, firmware and hardware base needed for follow-on implementations that will likely include custom printed-circuit boards. The system can be configured with standard definition analog cameras or 640x480 microbolometers available off-the-shelf from a range of vendors (e.g. DRS Technologies, FLIR, or L3 for example) including both long and short wave infrared. This is a key aspect of the longer term project for vessel and port sensing in fog, sensing ice structure variations, and use in emergency response scenarios such as fires, for security and safety. Likewise, the potential to host the camera in an AUV working with DHS center of excellence partners for subsurface oil detection under ice can be evaluated and explored to better define power, sizing, and integration requirements for use in AUVs. Likewise, the power, sizing and integration requirements for use with low-cost UAV systems will also be explored and defined for follow-up in the 2015/2016 period of performance.

Methodology

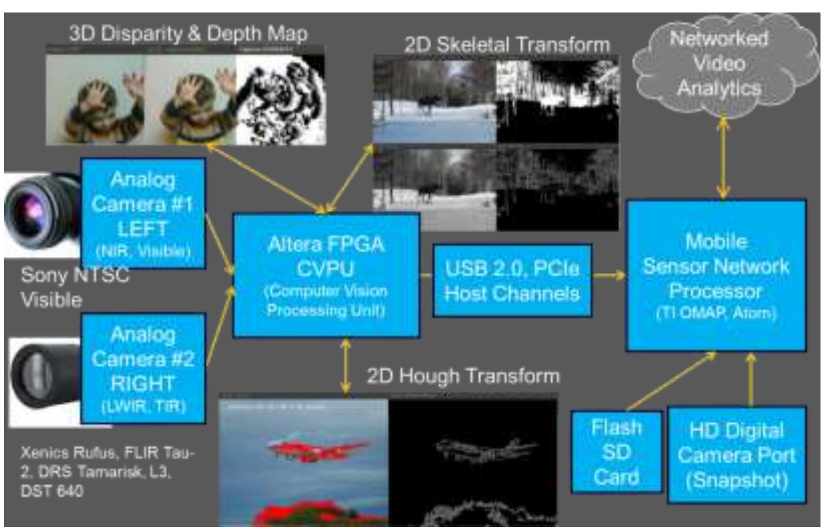
The Smart-Cam [Computational Photometer] will be executed through a 3-phase cycle of development.

Phase-1 (Year 1): Establish the baseline power, sizing, and capabilities using off-the-shelf components to construct a proof-of-concept Smart-Cam designed for drop in place on AUVs, UAVs, and on the ground in port environments. To accomplish this goal, we will form a team composed of Smart-Cam PI Dr. Sam Siewert, working under direction of Theme PI Dr. Kenrick Mock, along with students at University of Alaska Anchorage, graduate students at University of Colorado Boulder, Dr. Jim

Bellingham at Woods Hole, and key partners with the DHS Center of Excellence for Maritime technology. Dr. Siewert plans to construct a reference design, which can be replicated easily using all off-the-shelf components, and to define a software baseline using embedded Linux and OpenCV (Open Computer Vision). Power consumption, operational lifetime, sizing, mass, and performance for key security and safety monitoring and detection missions such as oil under ice detection will be the focus. The results will be a report with the configuration tested, power analysis, sizing and use on commonly available UAV/AUV/maritime vessels to DHS and government agencies in general, and recommendations for how to lower power use, increase performance and for configuration of phase 2 Smart-Cam. The hypothesis is that a custom PCB (Printed Circuit Board) with an FPGA (Field Programmable Gate Array) that implements acceleration for computer vision multi-spectral image fusion will improve the design, but this will be established by comparison to the phase 1 all software and OTS component version.

Phase-2 (Year 2): The Phase 1 configuration will be tested in AUV, UAV and port safety and security monitoring scenarios to establish key design changes compared to the OTS Phase 1 Smart-Cam. From this testing, we expect to make major design changes to packaging, data links, battery power and power electronics, and the image transform processing to incorporate an FPGA or co-processor designed for image fusion operations. Furthermore, the field testing will help establish the value of various off-the-shelf microbolometers and optics for specific uses like oil detection under ice in an AUV, but also for more general uses such as tracking and detecting vessels, animals, and people in fog and ice environments typical of the Arctic. The modular design of the Smart-Cam will allow us to test a wide range of infrared microbolometers (short-wave, long-wave, thermal) with visible CMOS (Common Metal Oxide Substrate) detectors, but also with ultraviolet. Previous studies have shown both positive and negative results for oil detection under thick sea ice and in, around, or on top of pack ice using these imaging bands in combination. The Smart-Cam will enable partners in this program to quickly change optics and detectors to evaluate effectiveness. The exit goal for this phase is clear design for the semi-custom integrating electronics board that is hypothesized to reduce power consumption, increase fusion performance, and enable OTS detectors and optics to be quickly changed in and out based on mission requirements. We won't know exactly what the Phase-2 Smart-Cam will look like yet, but we expect to make use of an FPGA or co-processors as depicted in Figure 2.

Figure 2: Improved Power Efficiency and Performance Smart-Cam Configuration



Phase-3: Assessment and Refinement (year 3 and beyond). At the end of year 2, we will assess the capabilities, flexibility, applicability, and cost effectiveness of our Smart-Cam system and document performance, options for OTS detectors and optics and provide publications and guidance to users for the lowest cost, most effective methods of providing security, safety, and hazard detection based on common mission types in the Arctic based on Phase-2 testing and any follow-on testing we can do in phase-3.

Stakeholder Engagement: A priority for our Phase-1 and Phase-2 work plan is to establish strong collaborations with our stakeholders. We have already engaged with Stephen Ribuffo, Port Director at the Port of Anchorage. We will engage appropriate personnel at the US Coast Guard, specifically the Research and Development Center - Capt. Evans, USCG RDC, and Mr. Bert Macesker, and District 17 – RADM Abel. Annual demonstrations of our current Smart-Cam configuration, software, and packaging will be provided to partners along with documentation so integrated tests can be planned to evaluate use of the Smart-Cam in real mission scenarios. Our intent is to embed the Smart-Cam and students working on the project with the Port of Anchorage and Coast Guard exercises as appropriate to field test the Smart-Cam sensor platform, fusion methodologies, link systems, and vessel and port cloud-based processing.

US MDA Challenges addressed: 4, 8,16.

Milestones

Year 1

1. Completed acquisition of components to build at least one proof-of-concept for bench testing. (3 months)
2. Completed achievement of capabilities to measure power consumption and battery characteristics for dual channel visible and visible+IR configurations. (6 months)
3. Completed installation of OpenCV on embedded Linux for lifetime testing with image fusion – visible + LWIR. (3 months)
4. Completed testing of an openCV embedded Linux lifetime with stereo visible mapping (disparity images and point cloud). (6 months)
5. Test and develop/refine Linux driver in V4L2 stack (Video for Linux, 2nd Edition) for NTSC-to-USB acquisition systems and document to improve custom PCB design for NTSC-to-FPGA-to-USB design in progress (future phases). (6 months)
6. Completed testing of uplink of images and streaming video over wireless b/g/n 802.11 for use in port environments and determine impact on power efficiency and battery lifetime. (6 months)
7. Define both software power saving options for TI-OMAP (Texas Instruments Open Media Applications Platform) and the Altera FPGA custom PCB in development for future phases. (6 months)
8. Completed delivery of documentation and instructions for building a test configuration for the Port of Anchorage for field testing in future phases. (6 months)
9. Submitted Invention Disclosure to University of Alaska Anchorage and submit peer-reviewed paper on power efficient Arctic sensor designs using low-cost-off-the-shelf components at a national or international conference or in a journal. (6 months)

At the end of Year 1 the system will be at TRL 5/6.

The work outline includes goals that go beyond this first phase, but are necessary to continue the work beyond May 31, so items are listed in priority order above.

Metrics Year 1

1. Power consumption per unit and battery characteristics for dual channel visible and visible IR configurations (what size battery and how long will it last). The target for year 1 is continuous operation for 6 hours on 8400 mAh (milliamp hour) Lithium Ion rechargeable battery. Six hours of no-recharge operation is the target metric, but the off-the-shelf solution will be characterized fully in terms of power consumption and lifetime as a function of resolution, frame rates, compression encoding and off-the-shelf visible or microbolometer cameras used.
2. Expected lifetime of unit. The target life expectancy is 50 years.
3. Impact on power efficiency by uplink of images and streaming video over wireless b/g/n 802.11 for use in port environments (how expensive in terms of power is it to upload). The goal for the first year is to provide only opportunistic uplink of images based on detected events and proximity of a user to the drop-in-place sensor rather than any form of continuous uplink or streaming. The target performance is 10,000 to 20,000 frames as an upper bound (approximately all data for 3 to 6 hours from one camera at 1 Hz or two cameras at 0.5 Hz).

The metrics described will be collected in bench test environments using current probes, by running the batteries to exhaustion, and with modulation of the image acquisition and processing workload, with unmanaged and managed power configurations. The goal of this phase is to fully characterize the best off-the-shelf low-cost configuration and to document limitations in a peer-reviewed publication along with proposals for computer vision co-processor architectures to improve performance. At the end of Year 1 the system will be at TRL 5/6.

The work outline includes goals that go beyond this first phase, but are necessary to continue the work beyond May 31, so items are listed in priority order above.

Year 2 Milestones

1. Incorporate FPGA or co-processor into image processing operations and refine power characteristics. (6 months) The goal is to address shortcomings in the operational life-time between recharges from year 1 for mono-vision, stereo vision, and visible + IR sensor fusion by off-loading the H.264 encode to the DSP and the disparity image and fusion computations to an FPGA based co-processor, thus reducing CPU workload, allowing for power savings through dynamic voltage scaling by idling the CPU as much as possible. This would result in either increased lifetime between recharges or continuous operations with smaller fuel cells or solar recharge subsystems. The ultimate goal for this work is not only intelligent selective uplink of data via computer vision processing for segmentation and recognition, but also to provide a method to continuously monitor on fuel cell power through the winter solstice and on solar recharge through the summer solstice in the Arctic.
2. Installed a SmartCam at the Port of Anchorage to enhance the port's security system purchased with previous funding from the DHS FEMA Port Security Program.
3. Complete multiple field tests at the Port of Anchorage. This will bring the system to TRL-7/8. (9 months)
4. Test capabilities in a variety of imaging bands for applications including detection of oil under sea ice. (12 months)
5. Develop power-aware multi-stage object detection with power/performance tradeoffs. (12 months)
6. Publish Year 1 results in conference or journal. (12 months)

Final phases will include significant work to ruggedize for Arctic operations with maritime vessels, AUVs, UAVs and to flight test with UAV/UAS.

Metrics

1. Power consumption per unit and battery characteristics for dual channel visible and visible IR configurations (what size battery and how long will it last). The target for year 1 is continuous

operation for 6 hours on a 8400 mAh (milliamp hour) Lithium Ion rechargeable battery. Six hours of no-recharge operation is the target metric, but the off-the-shelf solution will be characterized fully in terms of power consumption and lifetime as a function of resolution, frame rates, compression encoding and off-the-shelf visible or microbolometer cameras used.
2. Expected lifetime of unit. The target life expectancy is 50 years.
3. Impact on power efficiency by uplink of images and streaming video over wireless b/g/n 802.11 for use in port environments (how expensive in terms of power is it to upload). The goal for the first year is to provide only opportunistic uplink of images based on detected events and proximity of a user to the drop-in-place sensor rather than any form of continuous uplink or streaming. The target performance is 10,000 to 20,000 frames as an upper bound (approximately all data for 3 to 6 hours from one camera at 1 Hz or two cameras at 0.5 Hz).

The metrics described will be collected in bench test environments using current probes, by running the batteries to exhaustion, and with modulation of the image acquisition and processing workload, with un-managed and managed power configurations. The goal of this phase is to fully characterize the best off-the-shelf low-cost configuration and to document limitations in a peer-reviewed publication along with proposals for computer vision co-processor architectures to improve performance.

Outcomes, Output and TRLs
Year 1 and 2 Outcomes and Output

1. Off-the-shelf Smart-Cam reference as outlined in hardware budget section that can be replicated at same cost by any partner in the program using developed documentation, reference software, and tests.
2. Power analysis of baseline in various operational conditions including continuous monitoring, uplink, sleep states, and stand-by. Power-aware implementations of object recognition algorithms guaranteeing that the Smart-Cam object recognition performance is as good, in terms of true and false positive rates, as the performance of the reference implementation of the object recognition algorithm on a high-end desktop. Metrics 1 and 2.
3. Develop and demonstrate the Smart-Cam to the Port of Anchorage up to TRL 7/8. Metrics 1, 2, and 3.
4. Test results as to the potential for imaging in a variety of bands for applications including detection of oil under sea ice using AUV-mounted cameras.

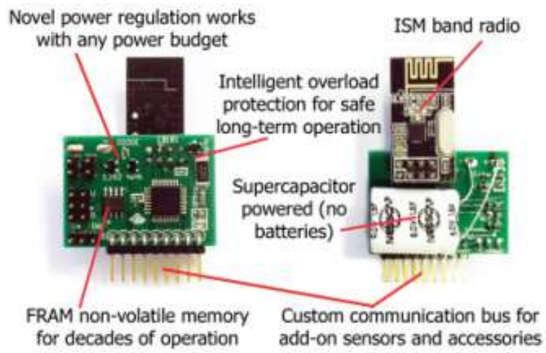
VII.2.c PROJECT: Low-Cost Wireless Remote Sensors for Arctic Monitoring

Principal Investigator: Dr. Kenrick Mock, UAA

Baseline

UAA's first startup company, Zensor™, develops low-cost wireless sensors for use in remote monitoring, asset management (SCADA systems), surveillance and security. The device uses a supercapacitor in combination with solar power for a 50+-year lifespan to automatically form a distributed wireless network with nearby devices while conserving power. Using off-the-shelf electronics, a Zensor™ device can sense humidity, light intensity, temperature, color, distance, thermal images, motion, orientation of a stationary object, GPS location, or gases. Each sensor collects data from all nearby sensors, which allows information to be collected by interrogating just one sensor in the network. A sensor node currently has a 50-100 meter communication range and can collect 200,000 data packets a day. Further details about Zensor™ are provided in US patent application publication No. 2013/0342355. It describes how the apparatus is comprised of a power unit to collect energy, a sensor unit to receive sensor data, memory in the form of non-volatile FRAM to store sensor data, a communications unit to wirelessly broadcast sensor data to other nodes in the vicinity, and a processing unit that can be configured to operate the sensor after the energy collected in the power unit reaches a specified threshold value (Figure 1).

Figure 1: Baseline Zensor™ Configuration



Objective/Purpose: The general goal is to improve the design of the Zensor sensor by developing variations of it, testing and deploying the improved low-cost sensors that can continuously monitor items or areas of interest in Arctic and marine environments. The devices, in turn, must be capable of opportunistically transmitting data to a remote server, maritime vessels and UAVs for analysis. Depending on the deployment scenario, the transmission mechanism may take many forms, such as transmission through a central hub, high altitude airship, human-operated vehicles, or automated collection from an autonomous vehicle in the vicinity. For this research, tradeoffs must be made between transmission parameters, power requirements, size, and computing functionality. This will require development of a new generation of sensors using the Zensor™ platform as a reference design. The development will include protocols to uplink data with minimal power use and with opportunistic uplink to maritime vessels and UAVs recognizing Arctic-specific communication challenges (intermittent satellite coverage, media bursts).

Initially we are targeting deployment at the Port of Anchorage as an experimental testbed for sensor development and tuning of the networking and transmission protocols. In particular, we will work on integrating storage and transmission of images and video using the Smart-Cam platform. Additionally, sensors may address monitoring of ice at the Port, including "candle dipping" or the accretion of tidal pier ice. A variety of sensors including visible, IR, distance, temperature, and direct measurement via ultrasonic or submerged pressure sensors can illuminate how and where the ice forms.

Ultimately the sensors will be deployable in a wide variety of locations and scenarios. Future sensor capabilities include integration with differential GPS for improved location accuracy, asynchronous and decentralized network architectures, deployment from UAVs or other vehicle to pepper a remote landscape for wide coverage, or the ability to adhere to vessels. Applications include monitoring water and ice flows/levels, oil detection, or vessel tracking.

Methodology

In Year 1 we will focus on setting up a local test bed where we can experiment with land and water-based sensors. The Port of Anchorage has emerged as a good fit based on existing needs and proximity to UAA. Dr. Aaron Dotson, Dr. Samuel Siewert, Dr. Kenrick Mock, Dr. Randy Moulic, Dr. Martin Cenek, and Dr. Don Spalinger will jointly develop the sensor technology. To implement the project we will do the following.

In Year 2 we will investigate ruggedization of devices for Arctic maritime environments and begin field testing in more remote locations along with efforts to test sensors that can detect oil in ice conditions, including remote sensing such as infrared imaging and water-based sensors using techniques such as UV fluorescence. We will also investigate new sensor designs and architectures including asynchronous sensor networks, and new solid-state, semiconductor, and electro-optic based technologies.

Stakeholder Engagement: A priority for our Phase-1 and Phase-2 work plan is to establish strong collaborations with our DHS stakeholders. We have already engaged with Stephen Ribuffo, Port Director at the Port of Anchorage. We will engage appropriate personnel at the US Coast Guard, specifically the Research and Development Directorate (Capt. Evans, USCG RDC). Development will be driven by our stakeholder needs.

US MDA Challenges addressed: 4, 8, 16.

Milestones (Year 1):

1. Develop communication protocol for ad-hoc sensor network.
2. Design sensor platform for Port of Anchorage scenario.
3. Measure power, data, and communication characteristics for sensors deployed in test bed.
4. Complete analysis of data received on COE server that ultimately will interface with the Integrated Intelligent System of Systems.
5. Deliver plan for building sensors and their configuration.
6. Submit invention disclosure for any new IP, apply for provisional patent.
7. Submit results for publication.

Year 2

1. Design sensors for operation in more remote environments.
2. Incorporate communication protocols and electronics for remote sensors.
3. Design and test a remote sensor network to detect deformation events indicative of ice instability and potential threats to infrastructure using on-ice GPS/GNSS Real-time kinematic sensing.
4. Computation in sensor-networks without a common clock (asynchronous networks).
5. Event sensing by decentralized, distributed sensor-networks that is resilient to failing components. (TRL 3)
6. Design and test early prototypes for sensor detection of oil under ice.
7. Design and test early prototypes for novel electro-optical sensors.
8. If patentable complete provisional patent application, then publish Year 1 results in peer-reviewed venue.
9. Integration of data from Low-Cost Wireless Remote Sensors for Arctic Monitoring into the IISoS.

Metrics

1. Data collection. This is a measure of whether the sensors are performing their fundamental task of collecting data and transmitting it. Our target is to receive/analyze at least 95% of the sensor samples.
2. Resiliency. This metric will measure the robustness of data in the event of device failure. The target is for continuous data coverage.
3. Power consumption will vary depending upon the deployment scenario (e.g. local infrastructure, communications requirements, etc.). The target for continuous operation is 1 year with a longer-term target of indefinite continuous operation until component failure under normal weather conditions.

4. Data and communication characteristics for sensors deployed in test bed: range, bandwidth, packet loss.
    a. Target ranges for sensor-to-sensor communications are at least 100m up to 2km and approximately 50km for communications to fixed infrastructure (e.g. node).
    b. Bandwidth targets range from Kbps range for low-data sensors to 10Mbps bursts for larger data sets (e.g. images, aggregate sensor data to fixed infrastructure).
    c. Packet loss target is no more than 5% but greater loss may be tolerated if bandwidth needs are still met.
5. Cost per sensor. Our cost target for sensors built using COTS components is a total cost of up to $20.
6. Life span of sensor platform. The target is a lifespan up to 50 years.
7. Failure rate. Our target is for a failure rate less than 1%, which is a reported failure rate of the Arduino board. More importantly, we must be able to determine if a sensor has failed (not transmitting, transmitting incorrect data) with near 100% certainty.

Outcomes and Output

(1) ad-hoc sensor networking protocols to uplink data with minimal power use and with opportunistic uplink to vessels and unmanned vehicles (TRL 6/7 by end of Year 2). Metric 4.
(2) low-cost sensor platforms that can collect data under a variety of applications and scenarios, including computational photometers (TRL 6/7 by end of Year 2). Metrics 1, 2, 3, 4, 5, and 7.
(3) integration to a system capable of acting on and visualization sensor data (TRL 6/7). Outcomes for later years include remote deployment, asynchronous network architectures, ruggedized devices, sensors developed specifically for oil detection, and integration with DGPS (TRL 2-4 by end of Year 2).

VII.2.d PROJECT - New class of propeller-driven Long-Range AUV for Under Ice Mapping of Oil Spills and Environmental Hazards

Principal Investigator: Dr. James Bellingham, Director Underwater Robotics Laboratory, Woods Hole Oceanographic Institution (Dr. Bellingham was previously at MBARI)

Abstract

The increasing level of commercial marine activity in high latitudes creates an ever growing risk of oil spills. Even in logistically accessible, ice-clear oceans, characterizing the extent and nature of a spill can be difficult as the Deepwater Horizon incident highlighted. We propose to develop an AUV-based approach leveraging a small, long-range system developed by the PI, called the Tethys Long-Range AUV (LRAUV). The LRAUV is helicopter-portable, allowing rapid response to incidents to provide situational awareness for first responders.

Baseline

The PI for this activity, Bellingham, draws on leading AUV work at both WHOI, where he is Director for the Center of Marine Robotics, and MBARI, where he was Chief Technologist prior to moving to WHOI. Both WHOI and MBARI have extensive AUV development capabilities, operational AUVs, Arctic deployment experience, and infrastructure for simulation testing of new vehicle missions. The new Long-Range AUV, Tethys, developed by the PI at MBARI, is uniquely suited for under-ice surveys. The vehicle is small, about 120 kg, easily handled, and has unparalleled range. As currently configured with a variety of sensors, the vehicle is routinely operated for week-long deployments at a speed of 1 m/s (2 kts). Endurance is currently ten days on secondary batteries, and two to three times this on primary batteries. The vehicle is shore-launched and recovered. Operators interact with the vehicle via an Iridium satellite link, recovering data snippets in near real-time and send new mission commands to the vehicle as desired.

The longest range mission to date is 1800km, and cumulatively the two existing vehicles have more than 5000 hours at sea.

Objective/Purpose

Our objective is to develop an Autonomous Underwater Vehicle (AUV) based capability to observe and sampling dynamic processes in the Ocean in order to characterize oil spills and other environmental hazards under ice.

Methodology

Tethys' variable buoyancy system provides useful capabilities for high latitude operations. Variable buoyancy enables more efficient operations at low speed, but also permits the vehicle to surface and sink at zero speed, which would allow the vehicle to surface in open water between ice floes, for example, for satellite communications and a navigation fix. Incorporation of a USBL system allows homing on a transponder, which would allow recovery of the vehicle through an ice hole.

The leaders in *Tethys* development, Bellingham (WHOI) and Hobson (MBARI), have extensive sea experience with AUV operations, including in the Arctic. Bellingham was involved in the response to the Deepwater Horizons incident. Bellingham and Hobson have also developed have developed a number of AUVs in addition to the Tethys platforms, including *ALTEX* the MBARI *Dorado* AUV, the *Odyssey II* AUVs, the Odyssey, the *CETUS* hovering AUV, and the *Sea Squirt*. WHOI has extensive facilities to support AUV development, including engineering labs, machine shop, and 10-m deep saltwater test tank.

Risks associated with under-ice and high-latitude operations are outlined below, along with our strategies for mitigating those risks.

- Magnetic compasses are a preferred heading reference because of their low power consumption and reasonable cost, however they perform poorly in proximity to the North magnetic pole. Careful attention to minimizing vehicle-induced magnetic influences on the compass and the use of compass calibration methods should ensure adequate compass performance. Our prior experience with high latitude navigation provides an excellent foundation for this work.

- Arctic surface waters can be quite fresh, creating a requirement that a vehicle manage a wider range of buoyancy. Tethys is uniquely suited to deal with this as it has a variable buoyancy system. Depending on the additional displacement of the cytometer package, the existing buoyancy system can be doubled in size to ensure adequate reserve buoyancy.

- Low temperatures can alter the property of certain materials (fluids too viscous, plastics below glassy transition, battery performance degraded, etc.). We will revisit the material choices for the vehicle to ensure the vehicles can be transported at low temperatures.

- A range of task-level control capabilities specific to under-ice operations will be required. For example, sampling near the ice may require reducing vehicle speed to zero, and using the buoyancy system to bring the vehicle up to the ice canopy. Also, vehicle behaviors for fault-detection and recovery will have to be less conservative. Usually vehicles will ‘bail’ to the surface at the first hint of failure, where they will either communicate home by satellite or be recovered. Under-ice, this is not acceptable, consequently the vehicle must be capable of operating even in the event of failures. The mission-level control architecture used for the LRAUVs is well suited for such demands [Godin, 2010].

- In shallow Arctic water, the ice canopy can ground on the bottom, creating a fully three-dimensional environment in which the vehicle must navigate. We will restrict AUV operations to regions where the water depth is much greater than the ice thickness. An upward-looking altimeter will provide the vehicle the ability to sense the overhead ice and navigate to avoid it in the same manner as AUVs navigate near the seafloor. The acoustic Doppler system will be useful in allowing the vehicle to measure local currents and time activity.

We will use several levels of navigation for the AUV. First, a GPS system built into the Tethys antenna will routinely obtain GPS fixes when the vehicle surfaces. Second, the vehicle will dead-reckon using a Doppler sonar to measure velocity relative to the bottom, and a compass for heading. Third, an ultrashort baseline (USBL) acoustic system will measure range and direction to a transponder and allow acoustically marking interesting sites for revisit by the vehicle.

Multi-Vehicle Operations

The *Tethys* was created specifically to carry biological and chemical payloads for long distances and times. The vehicles are small, about 30 cm (12 inches) in diameter, and easy to handle (Fig. 8). A

Figure 8. The Tethys LRAUV (foreground) is much smaller than the Dorado platform providing a cost-effective solution for multivehicle operations.

commonly used sensor configuration of the vehicle includes ADCP/DVL, CTD, a dissolved oxygen sensor, a nitrate sensor (ISUS), irradiance sensor, and a Wetlabs Ecopuck. Two vehicles have been built at MBARI to date and a third is under construction now. Deployments range from a few days to over three weeks, and are unattended by ships. The longest range mission to date was over 1800 km at a speed of 1 m/s. In that deployment from and to Moss Landing, CA, the vehicle operated as far as 500km from shore independent of a ship. Ranges two to three times as great can be achieved by operating at a speed of 0.5 m/ s with minimal sensors. Endurance can be maximized by using the buoyancy engine, which is a shifting internal weight, to trim to neutral buoyancy and drift at zero speed with minimal sensors. The vehicle is typically shore-launched and recovered, using a Boston Whaler to tow the vehicle between the harbor entrance and a boat launch ramp.

Operators interact with the vehicle via an Iridium satellite link. Communications with the vehicle are possible when it surfaces, at intervals that are determined by the operator. Over several years of operation, a web-based operator's portal has been developed (http://aosn.mbari.org/TethysDash/) which includes a display of science and engineering data (http://aosn.mbari.org/TethysDash/data/daphne/realtime/sbdlogs/2012/201211/20121127T053258/). On a secure portion of the site, there is a command interface and a variety of utilities such as an alert page, where operators can configure alerts to be sent to email or mobile phones on certain conditions.

As part of this project we will integrate a device into the LRAUV that combines acoustic communication (ACOMS) and ultra-short baseline navigation (USBL) functions. The acoustic communications capability will allow vehicles within a kilometer of each other to communicate while staying submerged. The USBL navigation capability provides each vehicle with the ability to measure range and relative direction to the other LRAUVs. Cumulatively these enable cooperative sampling with the three vehicles. MBARI is already testing one of the combined ACOMS/USBL systems on the Tethys LRAUV.

Observing and Sampling Dynamic Processes in the Ocean

Many classes of environmental hazards in the ocean environment manifest themselves in the ocean water column. Examples include spills of oil or other toxic materials and harmful algal blooms. These phenomena are particularly difficult to characterize as they typically have high spatial structure and are highly dynamic in nature. Further, while in situ sensors may provide indications of the presence of the hazard, typically water samples must be acquired to allow more definitive analysis. The performance of a sampling system will fundamentally depend on its ability to obtain samples that are scientifically meaningful. Most sampling protocols will require that vehicles sample relative to sensed features in the water column.

Front Detection and Sampling: Observations of the evolution of a physical feature, e.g., a front between upwelled water and older stratified water, has been demonstrated off the West Coast. A simple yet effective classifier – the vertical homogeneity of temperature – was used to differentiate upwelling and stratified water columns. With this classifier, the Tethys AUV could detect a front, and in April 2011 used that ability to locate and repeatedly map a front's evolution. The AUV transected the upwelling front 14 times over two days, providing a very high-resolution depiction of the front's evolution.

Sampling Thin Layers: A requirement of the proposed work is to be able to take samples with respect to concentrations of oil or aggregates of marine organisms. Algorithms for sampling vertical distributions of organisms or chemicals have been developed by Bellingham's research team and are routinely used to trigger water sampling on MBARI's *Dorado* AUV. We have developed an adaptive triggering algorithm for the AUV's gulpers to autonomously trigger the gulpers at fluorescence peaks characteristic of high phytoplankton abundance. The principle of the method takes advantage of the AUV's sawtooth (i.e., yo-yo) trajectory. In one yo-yo cycle, e.g., a descent leg followed by an ascent leg, the vehicle crosses the phytoplankton bloom twice, first detecting a strong signal (e.g. fluorescence) and then triggering the sample on the second pass. This algorithm has been successfully used by the *Dorado* AUV in numerous field programs for studying phytoplankton thin layers, intermediate layers of suspended sediment, and for capturing water samples in a deep hydrocarbon plume in the 2010 Gulf of Mexico oil spill.

AUV patch-tracking algorithm: Taking samples relative to horizontal variability is important also. Processes such as phytoplankton blooms appear in patches that evolve from initiation to decline. We developed an algorithm for an AUV to autonomously localize and track the center of a phytoplankton bloom patch based on *in vivo* chlorophyll *a* fluorescence. The algorithm takes advantage of the responsiveness of the AUV platform to minimize the chance of losing track of the patch and maximize the rate at which the patch center is revisited. Patch tracking was field tested using Tethys in April 2011.

These algorithms can be combined, for example to sample biological features relative to a physical structure like a front. An example of this was demonstrated in June 2011 in Monterey Bay, California. The Dorado AUV flew on a transect from an upwelling shadow region (stratified water column), through an upwelling front, and into an upwelling water column. Running our algorithms, the AUV successfully classified the three distinct water types, accurately located the narrow front, and acquired targeted water samples from the three water types. Molecular analysis of the AUV-acquired water samples shows that mussels, calanoid copepods, and podoplean copepods were most abundant in the upwelling shadow region and nonexistent in the upwelling water column. Calanoid copepods were moderately abundant in the water samples collected from the upwelling front.

Flexibility of the System to New Mission Packages

How would the USCG load sensor packages on the LRAUV, for example to enable detect/classify surface and semi-submerged targets at distance?

The current LRAUV achieves its high performance by tightly integrating sensor systems on the vehicle. Consequently integrating new sensors on the vehicle requires some level of non-recurring engineering to create the mechanical, electrical, and software interfaces to adapt the vehicle to carry and interact with the mission package. This has already occurred with several complex payloads, including integration of a water sampling and molecular probe detection system (the MBARI Environmental Sample Processor) and a turbulence sensing package. To ensure range and endurance of the integrated system is maximized, the sensor package might require modification also. Modifying an LRAUV in which payloads could be swapped on and off is possible, but would require a detailed understanding of the different payloads, and an engineering effort to create the modular capability.

Stakeholder Engagement

Intersection with FY14 RDT&E Project Portfolio:

Project 4701, Response to Oil in Ice, sponsor **CG-MER**, stakeholders **D9**, **D17**, **BSEE**, **USEPA**, **PAC-7**: Our project directly addresses the challenges identified in this project that revolve around detecting and tracking oil in ice and testing operational capabilities. We bring to bear pre-commercialization technologies with substantial performance improvement (factor of 3 to 10 in coverage) as compared to off-the-shelf systems.

Project 4702, Detection and Mitigation of Oil within the Water Column, sponsor **CG-MER**, stakeholders **BSEE**, **ICCORPR**: both WHOI and MBARI systems have been used for detecting and characterizing deep oil plumes (e.g. the Deep Horizon incident) and the instrumentation developed here both leverages and advances that earlier work.

Project 4703, Improve SMART Protocol Effectiveness, sponsor **CG-MER**, stakeholder **CG-MER**, **BSEE**: Our effort directly relates the modernization of special monitoring of applied response technology and methods.

Other intersection include with **CG-926**'s Arctic Operations Support project (6209) and Arctic Shield 2014 Technology Demonstrations (6210).

Metrics & Milestones

Milestones

1. (ML1) Identify and test oil detection sensors for under-ice characterization of oil spills appropriate for small, long-range AUV. (June 10, 2015)
2. (ML2) Completion of augmented AUV simulator and test scenarios addressing high-risk elements, including navigation and sensing systems, demonstrating capabilities in Alaskan waters. (January 1, 2016)
3. (ML3) Completed building/acquisition and delivery of a Tethys AUV with high-latitude navigation and oil sensors. (June 1, 2016)
4. (ML4) Collect navigation performance data at high latitudes (Oct 1, 2017)
5. (ML5) Process the data and tune navigation algorithms from the testing mission (March 1, 2017)
6. (ML6) Plan and perform adaptive mapping of oil surrogate (low latitudes). (July 1, 2017)
7. (ML7) Plan and prepare for observation mission in the Bering sea (March 1, 2017)
8. (ML8) Perform the planned observation high-latitude mission (Sept. 1, 2017)

Metrics

Note of explanation: in many cases only one number is specified. In this case, the number represents the expected 'as built' performance of the system. When two numbers are given, the first is for the first field test performance for that capability, and the last is for the Arctic field test performance.

1. Simulator fidelity for development, mission testing, and operator training
    a. Vehicle hydrodynamic performance:

        i. Metric: Pitch deviation from vehicle performance. Target: 20% rms error.
    b. Navigation performance:
        i. Metric: Reflects navigation errors accurately. Target: Same navigation drift rate.
    c. Environmental sensing:
        i. Metric: % of onboard environmental sensors modeled. Target: 100%.
2. Navigation accuracy:
        i. Metric % of distance traveled. Target: < 0.5%.
3. Reliability
    a. Time between required operator intervention (remote – e.g. via satellite)
        i. Metric: Mean Time. Target initially > 10 hrs, ultimately > 168 hrs
    b. Time between required operator recovery
        i. Metric: Mean Time. Target initially > 96 hrs, ultimately greater than deployment time.
4. Performance-specific measures
    a. Detection level of oil:
        i. Metric: Parts per billion in water. Target: < 50 ppb
    b. Range and endurance with high-latitude navigation and oil sensors:
        i. Metric: Range in km. Target: 300 km on secondary batteries, twice that on primary.
    c. Adaptive sampling performance - mapping of spill extent:
        i. Metric: Areal coverage km2. Target: 1000 km2 per vehicle per deployment.
5. Operator ease of use
    a. Logistical footprint
        i. Metric: Kilograms. Target: < 600kg.
    b. Ease of mission configuration
        i. Metric: Time to specify grid survey. Target: < 1 hr.

Outcomes, Output and TRLs
At present, no Arctic capable Long-Range AUV exists. Consequently the starting point technology readiness level of the system is level 2 - The technology concept and/or application formulated.

By the conclusion of the effort, we will have demonstrated a Long-Range AUV in the operating environment. Consequently the end-point TRL will be 7 - System prototype demonstration in an operational environment.

1. AUV simulator satisfying metrics under category 1 above.
2. An Arctic-capable Long Range AUV with oil detection sensor at TRL 7, with performance satisfying metrics in categories 2-5 above.

VII.3 Theme 3 E2E

Principal Investigator:
Dr. Don Spalinger, Professor, UAA
Email: despalinger@uaa.alaska.edu

Baseline: As described in our proposal, our E2E is an integrative effort which we will combine research products from our Themes 1 - 4 activities and other emerging technologies, and our industry partners' COTS products and integrate them into an intelligent system of systems (IISoS) and transition them to DHS stakeholders. The baselines of the components of the IISoS are described in the above Themes.

Objective/Purpose

To develop and build an end to end system- an Integrated Intelligent System of Systems (IISoS) - to collect and collate information from multiple heterogeneous sources and sensors to provide a high resolution representation of the state of the Arctic maritime domain both current and long term, and integrate technology with indigenous knowledge based perspective, so that stakeholders can make timely and effective decisions based on the best information available provided in the best format possible. The IISoS addresses the DHS visionary goal: Enable the Decision Maker: It affords a means for Incident Commanders to receive the right information, at the right level of detail, at the right time that can be immediately translatable into knowledge/action.

The multiple heterogeneous sources and sensors are illustrated in Figure 7, page16 of this proposed work plan, and an explanation follows, as well as of the projects and Theme they are associated with and how they interrelate within Themes and across Themes. The system of systems architecture encompasses the four stages of the OODA loop. Theme 1 Maritime Domain Awareness Project; Theme 2 Maritime Technology; Theme 3 E2E and Theme 4 Integrated Education. The integration of information from many data sources – will enable a remote command and On-Scene-Command to seamlessly integrate the Observe, Orient, Decide and Act aspects of response.

Observe - integrates Themes 1 and 2 to provide the new sensory system of the IISoS.

1. **Community Based Observer Networks (CBONS)** (currently on St. Lawrence Island) – **integrate an indigenous knowledge–based perspective with technology.** A unique opportunity to systematically observe and document Arctic environmental and globalization changes – vessel tracking, incursions, arctic sea ice. Project 1.a

2. **New Sensors** – (i) Zensor sensors that are low cost, low power (solar power) ad-hoc sensor networks for remote monitoring, vessel tracking, surveillance, climate change – ice flow and depth. (ii) The SmartCam system on a chip for video processing and analytics. Projects 2.b and 2.c

3. **New class of propeller-driven Long-Range Autonomous Underwater Vehicles** – platform to include detecting oil spills under ice and additional detection and monitoring. Project 2.d.

4. **Detect Arctic Ocean Vapor Sources –** Systems located in remote areas for continuous measurement and monitoring of non-radioactive stable isotopes – oil spill vapors, ice retreat Project 1.g

Orient

1. **Arctic Sea Ice and Storm Surge Modeling**, new system for high resolution (2X) now-casting and forecasting of sea ice in the NW passage that can be used to assist in navigation for search and rescue missions. Build on current models Projects 1.b, 1.d, 1.e, 2.c, and 2.d

2. **Oil Spill response:** new GNOME (General NOAA Oil Modeling Environment)– currently hind sight, new capabilities: high resolution models that incorporate sea ice, ocean currents and surges that assess, predict and monitor the effects of oil spills in the Arctic. Projects 1.b, 1.c, 1.e, 1.g, 2.b, and 2.d.

3. **Portable High Frequency Radar** for maritime observation in remote settings – contributes to mobile maritime domain awareness. Project 1.f

Decide – is the data fusion stage of the IISoS and provides **situational maritime domain awareness -** improve prediction, assessment, prevention and response safeguards. We will integrate a data fusion system developed by HSARPA.

1. Identifying and responding to navigation hazards in the presence of ice, achieve high fidelity vessel tracking, and improve capacity for search and rescue (SAR): Projects 1.a, 1.b, 1.e, 1.f, 1.g, 2.a, 2.b, and 2.c.
2. Oil spill response - Complexity created by wind driven currents, high ice velocities and steeper sea surface height gradients: Projects 1.b, 1.c, 1.e, 1.g, 2.a, and 2.d.
3. Protecting Arctic people and the environment – to include
4. Locating subsistence fishermen in Arctic waters that need to know when large vessels approaching – they do not have Automatic Identification System (AIS) or radar: Projects 1.a, 1.b, 1.e, 1.f, 2.a, and 2.b.
5. Determining effects of oil spill on environment and community on the shore: Projects 1.a, 1.b, 1.e, 1.f, 2.a, and 2.b.
6. Unintentional catastrophic events: Projects 1.b, 1.c, 1.d, 1.e, 2.a, 2.c, and 2.d.
7. Integrated Education will provide ice navigation training that includes a simulator. It will incorporate sea ice models developed in Theme 2: Projects 1.b and 1.e.

Act – **The fusing of the data by the IISoS and its capabilities for assessment and prediction models will** provide a format for rapid decision making and planning purposes. It will afford a means for Incident Commanders to receive the right information, at the right level of detail, at the right time that can be immediately translatable into knowledge/action.

• The 4D/RCS architecture of the IISoS and its data fusion models will provide this capability: Project 2.a.

A chart illustrating a draft roll up of milestones is in Appendix A, and will be refined by March 2015 to reflect developments.

Methodology

Our E2E effort is a build-test-build approach. The design of the IISoS is resilient so if a particular component fails or is replaced the system continues to operate. At the end of Year 1 we will issue a request for proposals RFP for projects to replace system components that were found not viable. The tasks are structured around the OODA Loop: Observe, Orient, Decide, and Act, as shown in Figure 1. The UAA Team of academia, industry and government has assembled a complete array of sensors, unmanned platforms, software, and communications systems, which will significantly improve maritime security. A major thrust of the E2E will be demonstration and evaluation of unmanned systems, sensors, HFR, and CBONS-SA in the vast harsh arctic environment. The projects will come from Themes 1 and 2 in this document.

The E2E program will be executed through a 3-phase cycle of development:

Phase I. (Year 1). Codify the IISoS Performance Criteria. To accomplish this goal, we will convene a

Project Development and Oversight (PDO) Group composed of members of the COE Administration and PIs, University and Industry partners, and Coast Guard and other stakeholders. Initially, the group will be tasked to (1) define the U.S. Coast Guard's priority gaps in fulfilling their missions relative to Arctic Maritime Awareness, (2) determine the critical data needs to accomplish this mission, (3) formulate objectives and goals for data fusion/analytics, and modeling, and (4) provide perspectives and recommendations for data visualization and decision support. Phase 1 will include review of current sensor technologies and methodologies including those described in other projects of the COE as well as potential or emerging sensors that may be relevant and cost effective for Arctic Maritime Domain Awareness missions. The oversight group will report annually to the Director of the COE and to the Strategic Planning Committee.

Phase 2. (Years 1 and 2). Stand up a prototype Control Center and demonstrate feasibility of systems architecture, data fusion capabilities, and decision support applications. The COE has selected two demonstration projects for the first year, including a ship tracking and monitoring demonstration coupling a human-based observing network (CBON), NAIS tracking, SAR satellite tracking, and UAV deployment in the Bering Strait near Gambell, Alaska. The second demonstration project focuses on an arctic man-made disaster scenario - an oil spill simulation that will test high resolution models of sea current and storm surge to predict oil spread, degradation, and dispersion, and provide decision-support models for response efforts. In the summer of Years 1 and 2, we will add additional capabilities to our Arctic oil spill scenario, including HF radar verification of current predictions, sea ice models, and oil-under-ice sensors. Both projects serve as proof-of-concept tests of our development environment, and represent a first cycle through our IISoS build-test-build process. Lessons learned will provide feedback for sensor performance and development, data coms and integration, data fusion and synthesis, and data visualization.

Phase 3: Assessment and Refinement (Years 2 and 3). At the end of Year 1, we will assess the capabilities, flexibility, applicability, and cost effectiveness of our system architecture, and make appropriate modifications, additions or deletions to the program/product to insure relevance to the DHS enterprise. Modifications for Phase 3 will necessarily include refinements to all elements of the Control Center, including the addition of relevant sensors and sensor platforms (AUV and UAV's), refinement of data coms and fusion software, data analytics, and data visualization and portal applications.

E2E is responsible for the timely transition of research to USCG adoption and utilization. In Year 2 the E2E team will start the transitioning to DHS stakeholders of the following ADAC products:

1. Sea ice and Ocean currents models to provide nowcasting and forecasting data to the Environmental Data Server for the USCG SAROPS. The E2E team will work on the transition with Mr. Arthur Allen, Oceanographer for USCG SAR mission, USCG Office of Search and Rescue. The transition will include testing and verification of the models.
2. Complete modular Arctic-specific Ice Navigation course plus modules plus simulator-based practical assessments. The E2E team will work with Ms. Mayte Medina, Chief of USCG Marine Personnel and Qualifications Division to assess and certify the Navigation course using the TRANSAS simulator.
3. Developing and testing a prototype of the IISoS with RADM Abel and LCMDR McGoey from USCG D17.
4. SmartCam installation at the Port of Anchorage to enhance the existing port surveillance system that was funded by the DHS as requested by the port Director.

To insure this process, E2E will evaluate each project on a yearly basis to determine progress toward a.) Implementation;

b.) Relevance to USCG needs and interests;

c.) Cost effectiveness (cost-benefit). In year 1, we will compare baseline TRL to end-of-year progress as indicated in the project description, evaluate or update transition timelines (has the investigator met target metrics for the project, and has it progressed to the anticipated TRL specified in the AWP), cost-benefit ratios, and evaluate performance metrics.

Our overall transition process is illustrated in Fig. 9 on page 58. The specific transition process for each project will be formulated and adjusted as we meet with the USCG, the Strategic Planning Committee, and the Steering Committee. As an example, of the transition the USCG District 17 has requested that we work with them to transition our IISoS as part of their initiative to develop an Arctic Data Fusion Center. The IISoS will be tested in two scenarios.

Scenario 1: A CBONs scenario will incorporate multiple CBON teams on the ground, AIS tracking databases and other ship locating and classification sources to search for and locate a ship or ships suspected of illegal activity. The UAA control center will serve as the C3I center for operations and communication links will be established or simulated to query USCG, the Port of Anchorage and Alaska first responder/Local EOCs and forward CBON information to them as well. The scenario will be a scripted simulation designed to show the effectiveness of the CBON's capability and highlight the requirements for command, control and communications.

Scenario 2: addresses the discovery and response to an arctic oil spill from either an ocean rig or tanker ship will, as with the CBON's exercise, highlight the command, control and communications requirements to support responders as well as demonstrate the utility of our Theme 1 ocean current prediction models.

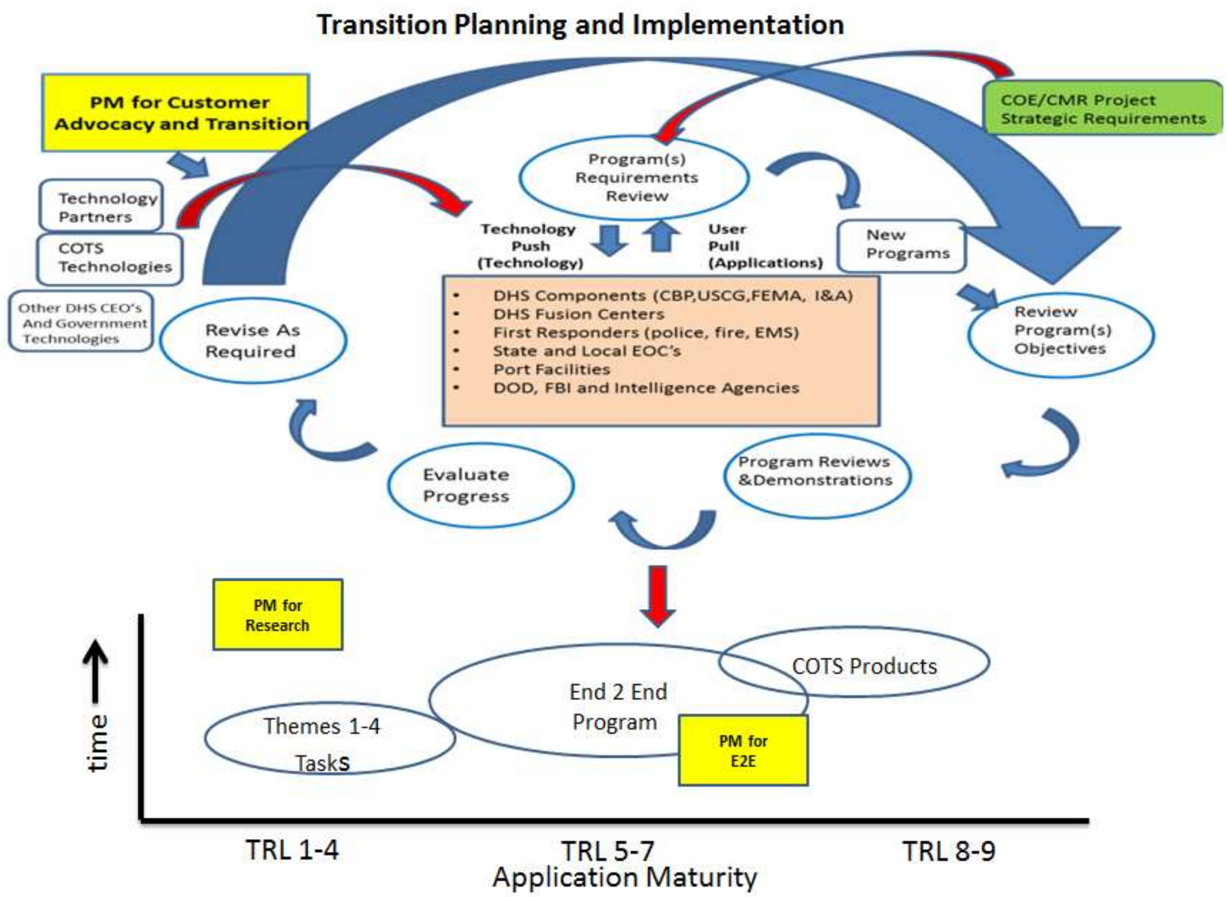


Figure 9: Transition Planning and Implementation.

Stakeholder Engagement: A priority for our FY15 and FY16 E2E work plan is to establish strong collaborations with our DHS stakeholders. We will engage appropriate personnel in the Pacific Area, District 17 CAPT Deer, LTCMDR McGoey, Mr. John McEntee Deputy Director, Borders and Maritime Division, DHS S&T, Mr. Steve Dennis, DHS HSARPA, and the Research and Development Center (Mr. Mark VanHaverbeke, USCG RDC), and Capt. Evans, USCG RDC to be members of our Project Development and Oversight group, aiding us in the development of the system and its functionality. Annual demonstrations of our Control Center will be presented to the U.S. Coast Guard and other DHS stakeholders for feedback on transition and implementation. Further, we intend to provide summer internships to several of our undergraduate and graduate engineering students each year. Our intent is to embed these students with Coast Guard exercises as appropriate (e.g., Arctic Shield Exercises) to field test sensors and sensor platforms, communication systems, and data acquisition and fusion methodologies.

US MDA Challenges addressed: 1, 2, 4, 5, 8, 12, 13, 16.

Milestones Year 1:
1. Completed a meeting with USCG and the RDC to determine system requirements.
2. Completed specifications for data formats and interfaces.
3. Completed HSARPA data fusion system is integration in our IISoS.
4. USCG District 17 has access to the data output from our IISoS.
5. Issued a RFP for projects to replace system components that were not viable.

Milestones Year 2:

1. Issued awards for projects identified via the RFP.
2. Completed testing, modifications and evaluations.
3. Host an Arctic Maritime Domain Symposium in Anchorage, June 2016. This could include sessions on all of the aspects we are working on: sensing, sensing platforms, data analytics and visualization, response technologies for oil spills in the Arctic, etc. Sponsors would include UAA, oil industry, etc.

Metrics:

1. Number of products integrated in the IISoS. Target number for Year 1: 2-3. Target Number for Year 2: 3-7.
2. Number of projects that reach their specific targeted TRL by the end of Year 1. Target number 7.
3. Number of projects that reach their specific targeted TRL by the end of Year 2. Target number 7.

Outcomes and Output
Years 1 and 2

1. An IISoS that will provide input to the USCG Arctic Data Fusion Center.
    a. HSARPA will be apprised on how their data fusion system performs with sensor data.

VII.4 Theme - Integrated Education

Theme Lead: Dr. Orson Smith
Email: opsmith@uaa.alaska.edu

VII.4.a PROJECT: "Arctic Education: Implementing the Arctic Strategy in Training"

Principal Investigator: Victoria Blackwood, Coordinator, Continuing Education, Maine Maritime Academy

Abstract
Maine Maritime Academy Continuing Education (MEMACE) will develop two hybrid courses in two years. An Ice Navigation (IMO model, STCW and USCG approved course incorporating the international Polar Code) with online knowledge based modules and hands-on simulation modules specific to the Arctic. A First Responder course with online modules and face-to-face sessions adapted to the Arctic maritime domain selected from MEMACE's five DHS/FEMA approvals. Both courses will incorporate results from COE work in Theme 2 notably Arctic Sea Ice models and Storm Surge Prediction models.

Baseline
The PI and Key Personnel are known to each other with the latter having written and taught for PI managed MEMACE since 2007. All are familiar with the equipment, general subject matter, methodologies and stakeholders for their respective project courses. The PI is connected and active with several LinkedIn Subject Matter Experts and Arctic related groups to stay current. PI has transited Norwegian polar waters (North Cape) and Alaskan (Glacier Bay) icy waters and served as a lifeboat captain, fire and lifeboat station monitor/drill participant while employed as a Crew Steward/Hotel crew member from 1979-1989 aboard the three (700 passengers /500 crew) 5 star globally positioned cruise ships of Royal Viking Line. Key Personnel have highest level of command experience in ship navigation and/or all hazards emergency response training in ice and or/polar waters. MMA has utilized TRANSAS

simulation equipment since 2009 and is a current member of NAMEPA whose awareness building of Arctic concerns and opportunities can be continued with input from this COE partner effort. MMA has an existing memorandum of understanding with IMQ Quebec CA and a long standing (20 years +) collegial relationship for faculty exchanges with MAKAROV Maritime Academy St. Petersburg, RU. Both Maritime Training institutions use TRANSAS software in their existing Ice Navigation courses.

Objective/Purpose

1. Develop a new Ice Navigation course specific to the Arctic incorporating Theme 2 research.
2. Adapt to the Arctic maritime domain an interagency directed First Responder course selected from MEMACE's five DHS/FEMA approvals.

Methodology

The Ice Navigation course specific to the Arctic will be designed as a hybrid modular course. This will allow sufficient flexibility to include the Polar Code once it is approved by the IMO for inclusion in STCW. The course will include a custom designed add-on to the TRANSAS simulator currently used by MMA. The course developers will incorporate Arctic Sea Ice and Storm Surge Predictions modeling developed by COE Theme 2 research. The hybrid full course will provide Ice navigation training for professional mariners and in-service DHS/USCG navigation personnel. Stand-alone online knowledge based modules will be made available to COE academic and Alaskan first responder training communities for continued MDA research, DHS educational and response planning purposes. MMA developed/USCG approved online knowledge based modules, plus Arctic training scenarios adaptable to KONGSBERG simulation software will be offered to the Seward, Alaska, based AVTEC Maritime Training Center for delivery on a shared tuition basis. This collaboration will add an additional USCG approved site for the IMO model Course to maximize its accessibility and best serve Arctic bound navigators.

The First Responder course selected from MMA's approved DHS/FEMA series for adaptation to the Arctic MDA during the initial two year COE project period is ME-002-PROTECT "Command Strategies and Tactics for Marine Emergencies" (CSTME). This course complements UAA research, DHS/OUP academic program goals, resolves an identified project weakness, and supports Arctic MDA. CSTME serves the entire Alaskan Maritime Domain First Responder Community including but not limited to management and operational personnel for Alaska Emergency Management Regional Response Teams, Alaska Department of Environmental Conservation, District 17/USCG, local Fire Departments, Law Enforcement, EMS, FBI, Port facility /Marine Terminals personnel, Customs and Border Patrol, ICE and native CBONS/coastal residents. Online knowledge based modules as well as face to face sessions will be customized to Arctic MDA under the shared guidance of MEMACE partner and CSTME providers at Tri-State Maritime Safety Association http://www.trimsa.org/training.html , The Port of Anchorage, District17/USCG and Alaska Emergency Management to affirm an interagency command structure among public/private stakeholders, agencies and missions while focusing on implementing solutions. Arctic specific online knowledge based modules will be made available to COE academic and Alaskan first responder communities for ongoing MDA research, DHS educational and response planning purposes.

The Ice Navigation course component of Maine Maritime's integrated Education CRM project will improve the performance of DHS/USCG mission areas of ice operations, marine safety, aids to navigation, maritime environmental protection, ports, waterways and coastal security and search and rescue by providing academic and continuing Education online knowledge based course modules, an accompanying undergraduate student managed FB page and/or Linkedin blog on MMA research areas, and hands on ice navigation simulation training for future and practicing professional mariners and DHS in-service USCG active and reserve afloat personnel. The First Responder (regionally tailored) courses component will improve the performance of DHS/USCG mission services areas of ports, waterways and coastal security, drug interdiction, search and rescue, marine safety, defense readiness, migrant interdiction, marine environmental protection and other law and border enforcement by gathering stakeholders from multiple response agencies to share and clarify Command strategies and tactics for marine emergencies in order to instill common maritime domain and vessel operations knowledge to shoreside responders called to a maritime domain incident. The courses will provide practice opportunities for operating in a unified command structure by joining members from multiple agencies in face-to-face and virtual teams to work through relevant scenario(s) in our DHS/FEMA approved awareness course Maritime Security for Military, First Responders and Law Enforcement Personnel. As time and funding allow, additional DHS/FEMA approved courses like Emergency Medical Operations in the Maritime Domain and Tactical Boat Operations could be adapted to winter maritime response needs in District 9.

An expansion of the scope of UAA's Integrated Education area to address winter maritime transportation operations and response on the Great Lakes (USCG District 9) is a logical addition to our COE's currently approved ADAC program. USCG Districts 9 (Great Lakes and St. Lawrence Seaway) and 17 (Alaska) have much in common as well as some distinct differences. District 9 has a long history of commercial lake and seaways fresh water ice navigation and maritime domain First Responder challenges in winter. Both Districts have shared waterways requiring bi-national cooperation to ensure safety and security of their regions and the respective citizens and visitors from the US and Canada. Both protect extraordinarily fragile and globally important marine environments that would be devastated by an oil spill or other hazardous spill of significance. Maine Maritime's project areas would as we will, in the next two- to three-year program, intentionally build navigation and first responder scenarios utilizing UAA's experimental research technologies to improve maritime domain awareness for varying levels (HS to Graduate School) of DHS/USCG academic and professional maritime and continuing education.

A. ICE NAVIGATION. Expansion of the ice navigation course to cover Great Lakes winter transits would require the addition of several chapters devoted to fresh versus salt water navigation. Each Great Lake has its own unique set of challenges impacting ice density and movement. Lake versus ocean wave behavior is different. Lake storms come up quickly on vast areas of water making them harder to navigate than ocean storms. For example, **Lake Michigan**'s dearth of safe harbors in expansive prevailing winds and rapid current shifts around the Straits of Mackinac require an exceptionally well-trained mariner to keep a vessel on course or escape a storm. **Lake Erie'**s shallow muddy waters require extra vigilance to prevent vessel groundings. **Lake Superior**'s cold temperatures, rocky coastline, and great depths create huge waves that break sharply versus rolling swells on the ocean. Maine Maritime's PI and lead researchers would work with Great Lakes Maritime Academy's Maritime (GLMA) Transportation and Marine Engineering students and faculty to exchange ocean and lake course modules and credits. GLMA students and MMA students could also investigate winter maritime transportation studies and research projects in US Great Lakes border states' University Systems of MN, WI, IL, MI, IN, OH, PA and NY then create teamed projects relevant to winter navigation training for Great Lakes coastal economic sectors engaged in in maritime trade, fisheries, recreation, environmental protection and transport. As interest grows, shared faculty research and student exchanges would encourage GLMA students to experience Maine's ice navigation training simulation and MMA students visits to GLMA's and other Great Lakes university programs at lakeside ports and campus testing facilities to enhance the education and practical experience of undergraduate and HS STEM students whose families live and work on winter Great Lakes waters.

B. FIRST RESPONDER COURSES will be developed in Year 3. Early research to compare and contrast best practices for EMR in USCG Districts 9 and 17 would bring together a vast knowledge base. Uncovering the EMR response methods and organizational infrastructure for each Great Lake state(s)' maritime first responders would identify training areas of greatest need so courses could be crafted with local help to improve regional response and provide data to

USCG/DHS in support of improved infrastructure. Using topical content from documents like District 17's DRAFT Programmatic Environmental Assessment Arctic Operations and Training Exercises May 2014/ District 9's reports on the need for improved response tactics to underwater oil pipeline breaches/ The safety Profile of the Great Lakes-St. Lawrence Seaway System March 2014/ and the comprehensive related annual Arctic Maritime conferences organized by the Company of Master Mariners of Canada Maritimes Division - including 12 area-specific power point presentations on "The Evolving Arctic Challenges and Opportunities April 2014".

Stakeholder Engagement
Mr. Mark VanHaverbeke, USCG RDC and Ms. Mayte Medina, Chief of USCG Marine Personnel and Qualifications Division, CDR Eric Peace, Chief, Mobility and Ice Operations Division (CG-WWM-3).

US MDA Challenges addressed: #4: Understanding Maritime Activity, #8: Shared Situational Analysis Capability, # 12: Fusion and Analysis for Maritime Personnel.
http://www.whitehouse.gov/sites/default/files/docs/national_maritime_domain_awareness_plan.pdf p30

Metrics & Milestones
Milestones

1. Developed 6 of 11 ICE Navigation course online modules. (June 30, 2015)
2. Developed remaining 5 online modules plus simulator-based practical assessments to be included in the instructor manual. (January 2016) for a new ICE Navigation STCW IMO model course. Submitted to USCG for approval (June 30, 2016)
3. Completed a pilot delivery of the IMO model course for selected DHS/USCG navigators transiting US Polar waters (June 30, 2016)
4. Completed adaptation to a blended delivery of CSTME, a 2.5 day classroom-based Maine DHS/FEMA approved course for application to joint command effective response to incidents in the Alaskan Arctic's maritime Domain. (June 30, 2017)

Metrics
1. **ICE NAVIGATION COURSE** Level of achievement:
a. Completed one or more of 6 existing online modules by June 30, 2015
b. Completed one or more of 11 **total** online modules by June 30, 2016
c. Completed all online modules plus hands-on simulation at MMA (non IMO model) June 30, 2016
d. Completed all online modules plus hands-on simulation at AVTEC (non IMO model) June 30, 2016
e. Completed Full STCW IMO model course certifications MMA+AVTEC 6.30. 2016**
**NOTE: USCG approved STCW *IMO MODEL* course readiness is dependent upon IMO ratification of Polar Code for STCW/ and USCG course approval (US mariner required certification) is secured. Average USCG original course approval review process takes 120 days.

2. **FIRST RESPONDER (CSTME COURSE)** Level of achievement:
   a. Stakeholder working group identified/ briefed (SKYPE/email) course content (generic)
   b. Course instructors familiarized with LMS and generic content modules 1-4 uploaded
   c. Stakeholder working group convened and Arctic specific course content defined
   d. Course instructors complete upload of all 16 Arctic specific modules
   e. Stakeholder working group completed Arctic online modules 1-08
   f. Stakeholder working group completed all Arctic online modules1-16+pilot date set
   g. Alaska stakeholders Completed online modules 1- 16
   h. Alaska stakeholders Completed online modules and live pilot session at COE
   i. Stakeholder working group After Action review and report completed

Outcomes and Output

ICE NAVIGATION COURSE Number of modules or full course enrollments per student per date
a) 30-150 **b)** 150-300 **c)** 24-36 DHS/USCG **d)** 24-60 DHS/USCG **e)** 24 –60 DHS and/or Mariner

FIRST RESPONDER (CSTME COURSE) Working group or Stakeholder online modules completed pilot course completed and After Action review and report completed by date.
a) July 30, 2016 **b)** August 30, 2016 **c)** September 30, 2016 **d**) December 30, 2016 **e)** December 30, 2016 **f)** March 30, 2017 **g)** May 30, 2017 **h)** June 15, 2017 **i)** June 30, 2017

VII.4.b PROJECT: Minority Serving Institutions (MSI) outreach

Principal Investigator: Marva Watson, Director, Diversity, UAA

Ms. Marva Watson, UAA Director of Diversity, will serve as the COE ADAC Director for MSI. This position was created to ensure that MSIs are engaged in the COE. She will suggest, develop and implement plans to engage MSIs, and will work closely with the COE Director, Director, Integrated Education, and Theme Leads, and serve on the Strategic Planning Committee.

Baseline

UAA and its university partners are putting into motion plans involving MSIs. This will build on policies and practices already in place at these institutions to engage MSIs. The COE will use the Executive Committee and Strategic Planning Committee to maximize the participation of an under-utilized community of academic research that is found in the community of MSIs. UAA and its team members each have histories of engagement with MSIs, believing that diversity of participating entities brings a broader and increased exposure of new ideas and innovations both in research and its application.

Objectives

Ms. Watson is currently involved with attracting faculty and students from HBCUs to UAA and participates in the “Institute on Teaching and Mentoring” conference sponsored by the Compact for Faculty Diversity, where UAA has successfully recruited outstanding faculty from MSIs. She will be attending the conference again this year. Ms. Watson will initiate discussions at this meeting and has UAA specifications for graduate and post-doctoral students for possible recruitment.

She will work closely with the COE Director and the Director of Integrated Education and serve on the Strategic Planning Committee to ensure MSIs are integrated into the planning process.

The COE will host a “Diversity Day” conference at UAA for MSIs - faculty and students – to discuss research related to DHS. We could also sponsor such events at partner institutions and videoconference with the COE in Anchorage. Student attendees would be invited to apply for internships at the COE for a hands-on experience of solving DHS problems, attend special summer “camps” designed to work on projects from the center, or work-study programs for financially constrained students to take courses that prepare students for careers to benefit DHS.

We would also have an exchange program for faculty from the MSIs to work at the center, and our faculty to spend time at their institution. With the selected partner institutions, we would develop online courses related to DHS and other joint curriculum for courses related to DHS as proposed in our Integrated Education Theme. They will also be involved with other research themes where appropriate.

Partner MSI institutions would participate in the Executive Committee meetings of the SPC.

The engagement of MSIs will not be limited to university research. The UAA team possesses significant commercialization capability, which currently includes MSI participation. For example, work with academic researchers at MSIs to develop, transition, and commercialize research and intellectual property and their participation with the Theme 5 E2E process.

Milestones and Metrics

Milestones Year 1

1. Establish potential MSIs to participate in the ADAC at the "Institute on Teaching and Mentoring" conference sponsored by the Compact for Faculty Diversity.

2. Provide names of potential graduate students from the "Institute on Teaching and Mentoring" conference sponsored by the Compact for Faculty Diversity.

Create and finalize plans for a "Diversity Day Conference" for students and faculty participants at UAA to be held Year 2.

3.

4. Create a draft of the MSI Strategic Plan for the ADAC, together with the Strategic Planning Committee.

Stakeholder Engagement

Ms. Stephanie Willet, Education Director, Office of University Programs (OUP).

Metrics Year 1

1. Number of MSIs contacted to participate in the UAA ADAC.
2. Number of graduate students for recruitment.

Milestones Year 2

1. Sponsor a "Diversity Day Conference" for students and faculty participants at UAA.
2. Complete and implement the MSI Strategic Plan.

Metrics Year 2

1. Number of attendees at the Diversity Day Conference.
2. Number of students recruited.

VII.4.c PROJECT: Integrated Arctic Maritime Education

Principal investigator: Dr. Orson Smith

The UAA COE Team will design, develop, implement, and demonstrate an innovative, comprehensive educational system to satisfy or exceed the requirements of Topics 6a through 6h presented in the FOA. In particular, we will provide an experiential learning experience and scholarships for undergraduates and graduate students to include academic coursework and active research. We will provide an affordable education to a greater diversity of students through work-study, apprenticeship, and internship programs. We will reach out beyond degree students to: recruit high school students using hands-on simulation gaming; engage first responders with virtual training facilities and continuing education; educate others in academia, government, and industry about homeland security with traveling seminars short courses.

Our degree and certificate homeland security educational offerings will be delivered using the entire spectrum of academic environments: on-campus bricks-and-mortar; distance learning via asynchronous and synchronous online; and seminars and short courses to be offered at other academic institutions, government agencies, and corporations. Selected presentations and courses will also be freely available for downloading from the COE website.

This project combines the full range of activities needed to create a vibrant, current, and attractive Arctic education educational program.

Scholarship-supported undergraduate and graduate study at UAA and ADAC partner institutions are to be advertised nationally, specifically targeting minority students, and awarded annually with the goal of recruiting and advancing qualified candidates toward leadership roles in maritime safety and security-related careers. This will be done in collaboration with Marva Watson, Director Diversity at UAA, and the Director for MSI for the UAA ADAC.

Baseline
Existing specialty course curricula at UAA would be refined to increase Arctic emphasis, increase DHS mission relevance. Adjusting the existing materials for distance delivery will increase appeal and availability to DHS professionals around the world as well as to graduate students seeking leadership roles in maritime safety and security-related careers. In particular, refinements will be done to the existing Coastal Ocean and Port Engineering (COPE) program. Nationwide advertisement of the COPE program will be specifically directed to Minority-Serving Institutes.

Only dated general guidance for Arctic port design exists. Conference papers on diverse aspects of cold regions port design exist, such as through the Port and Ocean Engineering in Arctic Conditions (POAC) conferences. No compendium of current knowledge on the topic has been published

Objective/Purpose
1. Recruit and advance qualified minority and other candidates toward maritime safety and security-related careers.
2. Define critical challenges and achievable ends to improve maritime safety and security and disseminate this information and associated technological advances to DHS leaders and others with related responsibility.
3. Creation of compendiums of the current knowledge in Arctic studies.

Methodology
Engage UAA faculty specialists, who will in turn solicit contributions from other experts, to draft a manuscript to the standards of the ASCE TCCRE monograph series. Priority chapter topics will be specified by DHS sponsors and through discussions at annual Marine Safety and Security Workshops. Chapter topics will subsequently be presented as professional development short courses in conjunction with annual Workshops. Publication will be credited to ASCE TCCRE and to DHS.

The refinement of specialty course curricula to increase Arctic emphasis, increase DHS mission relevance, and adjust materials for distance delivery will increase appeal and availability to DHS professionals around the world as well as to graduate students seeking leadership roles in maritime safety and security-related careers. Nationwide advertisement of the COPE program will be specifically directed to Minority-Serving Institutes. The full sequence will be repeated annually.

Host a workshop with invited speakers for participants in DHS and in Alaska government and industry with maritime safety and security-related missions and expertise. External agency and industry sponsorships will supplement ADAC resources to host the workshop. Proceedings will be published. Self-supporting professional development short courses will be conducted in conjunction with the workshop.

Advertise scholarships nationally, specifically targeting minority student populations, with aid from DHS agencies. Award scholarships to students enrolled in degree programs that lead toward maritime safety and security-related careers. Monitor progress of scholarship awardees, offering counseling and other support to help assure success.

Stakeholder Engagement
DHS will participate in

1. The compilation by specifying priority chapter topics and by review of draft editions of chapters and the full manuscript. DHS will be prominently acknowledged as co-sponsor with ASCE TCCRE of the final publication.
2. The advertisement of the COPE program, particularly to their own employees, and are informed of this specialized maritime safety and security-related graduate degree program at UAA. Sponsorship of DHS employees to enroll in COPE courses will fit existing agency professional development programs.
3. The workshop program and be acknowledged as the primary workshop sponsor. Proceedings summarizing workshop discussions will be provided. The first workshop will be held in July 2015.

Milestones

1. Conduct the first in the ADAC workshop with invited speakers for participants in DHS and national and international experts on best practices in prevention of disasters in international Arctic waters. (July 2015)
2. Acquire external sponsorships for the 2016 ADAC workshops (October 2015)
3. Conduct workshop (January 2016)
4. Creation of scholarship program and advertisement of the scholarship program (January 2016)
5. Publish workshop proceedings (February 2016)
6. Award Scholarships (August 2016)
7. Complete initial delivery

CE A674	**CE A675**	**CE A676**	**CE A677**	**CE A678**
Dec 2015	Apr 2016	Dec 2016	Apr 2016	Dec 2016

8. Begin compilation of compendium materials (August 2015)
9. Detailed table of contents completed; draft compilation 50% complete (August 2016)

Metrics

1. Enrollment sizes of the courses and the certificate program (enroll 8 – 15 per course; target 10)
2. Level of achievement of the learning outcomes of the courses and the certificate program (100% of learning outcomes achieved by all course enrollees)
3. Number of secondary schools, DHS agencies, and other institutions receiving advertising materials (target 100)
4. Number of students awarded scholarships (depends on funding yet to be allocated; target 2 per year through UAA ADAC)
5. Number of minority students awarded scholarships (target 1 out of 2 per year)
6. Number of scholarship awardees who complete a full-time academic year's successful progress toward their targeted degree completion (100%; target all awardees)
7. Compendium completion based on pages and chapters completed.(100% complete – August 2018)
8. Size of external sponsorship for the workshop ($5,000 – $25,000; target $10,000)
9. Workshop attendance (50-150; target 100)
10. Impact factor/number of citations of the published proceedings (10-30 citations within a year; target 15)

Outcomes and outputs

1. DHS professionals and candidates for DHS-relevant careers will gain specialized practice-oriented education in Arctic coastal, ocean, and port engineering relevant to maritime safety and security in Alaska and cold regions of the world. Metric 1.
2. Scholarship awardees advance toward maritime safety and security-related degree completion. Metric 6.

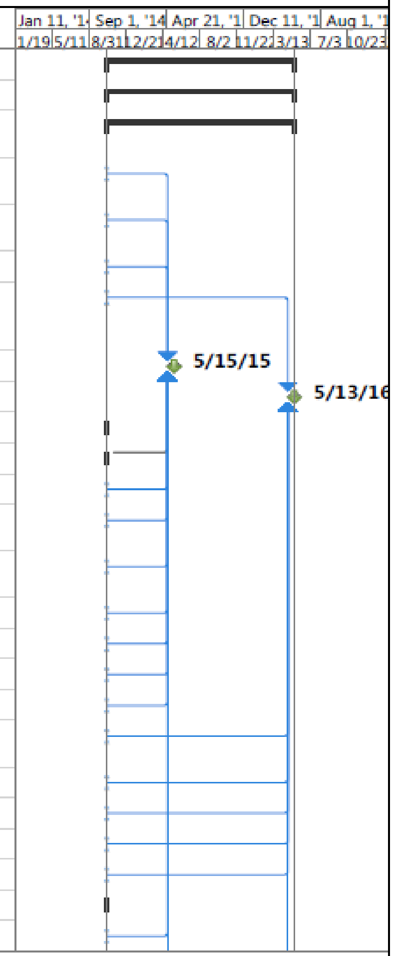
3. Secondary school counselors and students viewing scholarship advertisements become aware of maritime safety and security-related career opportunities. Metric 3.
4. Maritime safety and security-related degree programs are strengthened by the scholarly activities of scholarship awardees. Metrics 2, 4, 5, and 6.
5. Knowledge of DHS-relevant maritime safety and security challenges and technological advances will be disseminated at the workshop, resulting in new ideas and more energy focused on priority challenges. Metrics 7, 8, 9, and 10.

Appendix A

Roll up of Milestones

UAA DHS COE CMR Workplan Milestones DHS COE 2v4 Piccard 102314

ID	Task Name
1	**THEME 3: E2E SCENARIO 1- Ship Tracking and Monitoring Demo**
2	**II.1 THEME 1 - MARITIME DOMAIN AWARENESS PROJECT**
3	**II.1.a. PROJECT - Community Based Observer Networks for Situational Awareness (CBONS-SA)**
4	Pilot data flows and datasets consisting of images, meta-data, narratives and context that are spatially explicit (output).
5	A tested protocol for HFOs to observe, detect, and record a range of variables that are critical to maritime security under different environmental conditions (outcome).
6	An operational communication system for real time data flows from offshore HFO (outcome).
7	An operational CBON comprising two Bering Sea communities (one Northern Bering Sea; one Southern Bering Sea) that apply tested protocols for HFOs and demonstrates real-time transmission of observations.
8	Milestone #1: Proof of Concept (May 2015)
9	Milestone #2: Prototype Integrated Solution (May 2016)
10	**II.2 THEME 2 - MARITIME TECHNOLOGY**
11	**II.2.a PROJECT- Integrated Intelligent System of Systems.**
12	Completion of a scenario and demonstration design to illustrate its capabilities.
13	Design and implementation of the 4D/RCS and its code within the scope of the demonstration scenario.
14	Completion of the VVT for demonstration scenario the 4D/RCS, IISoS, and integration with MSARS
15	Successful completion of the scenario demonstrations.
16	Documentation for the 4D/RCS (e.g., a user's manual) and IISoS.
17	Establish necessary connections with the portal of USCG in Juneau.
18	Successful incorporation of data fusion methods developed by HSARPA.
19	Incorporation of additional sensors that includes CBONs, satellite, UAV, Smart-Cam, and other sensor networks.
20	Completion of additional scenario and demonstration design.
21	Knowledge representation and development to act upon additional sensor inputs and their VVT.
22	Successful completion of the new scenario demonstrations.
23	Write and submit project results to peer-reviewed venue.
24	**II.2.b PROJECT- SmartCam Annual Work-plan Smart-Cam [Computational Photometer]**
25	Acquire components to build at least one proof-of-concept for bench testing.(3 months)



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UAA DHS COE CMR Workplan Milestones DHS COE 2v4 Piccard 102314

ID	Task Name	Jan 11, '1 · Sep 1, '14 · Apr 21, '1 · Dec 11, '1 · Aug 1, '1 (1/19 5/11 8/31 12/21 4/12 8/2 11/22 3/13 7/3 10/23)
26	Achieve capabilities to measure power consumption and battery characteristics for dual channel visible and visible+IR configurations.(6 months)	
27	Install OpenCV on embedded Linux for lifetime testing with image fusion – visible + LWIR (3 months)	
28	Complete testing of an openCV embedded Linux lifetime with stereo visible mapping (disparity images and point cloud).(6 months)	
29	Test and develop/refine Linux driver in V4L2 stack (Video for Linux, 2nd Edition) for NTSC-to-USB acquisition systems and document to improve custom PCB design for NTSC-to-FPGA-to-USB design in progress (future phases).(6 months)	
30	Test uplink of images and streaming video over wireless b/g/n 802.11 for use in port environments and determine impact on power efficiency and battery lifetime.(6 months)	
31	Define both software power saving options for TI-OMAP (Texas Instruments Open Media Applications Platform) and the Altera FPGA custom PCB in development for future phases.(6 months)	
32	Deliver documentation and instructions for building a test configuration for the Port of Anchorage for field testing in future phases.(6 months)	
33	Present finding to University of Alaska Anchorage and submit peer-reviewed paper on power efficient Arctic sensor designs using low-cost-off-the-shelf components at a national or international conference or in a journal . (6 months)	
34	Incorporate FPGA or co-processor into image processing operations and refine power characteristics. (6 months)	
35	Complete multiple field tests at the Port of Anchorage.(9 months)	
36	Test capabilities in a variety of imaging bands for applications including detection of oil under sea ice. (12 months)	
37	Publish Year 1 results in conference or journal. (12 months)	
38	**II.2.c PROJECT- Low-Cost Wireless Remote Sensors for Arctic Monitoring.**	
39	Develop communication protocol for ad-hoc sensor network.	
40	Design sensor platform for Port of Anchorage scenario.	
41	Measure power, data, and communication characteristics for sensors deployed in test bed.	
42	Complete analysis of data received on COE server that ultimately will interface with the Integrated Intelligent System of Systems.	
43	Deliver plan for building sensors and their configuration.	
44	Submit invention disclosure for any new IP, apply for provisional patent.	
45	Submit for publication.	
46	Design sensors for operation in more remote environments.	
47	Incorporate communication protocols and electronics for remote sensors.	

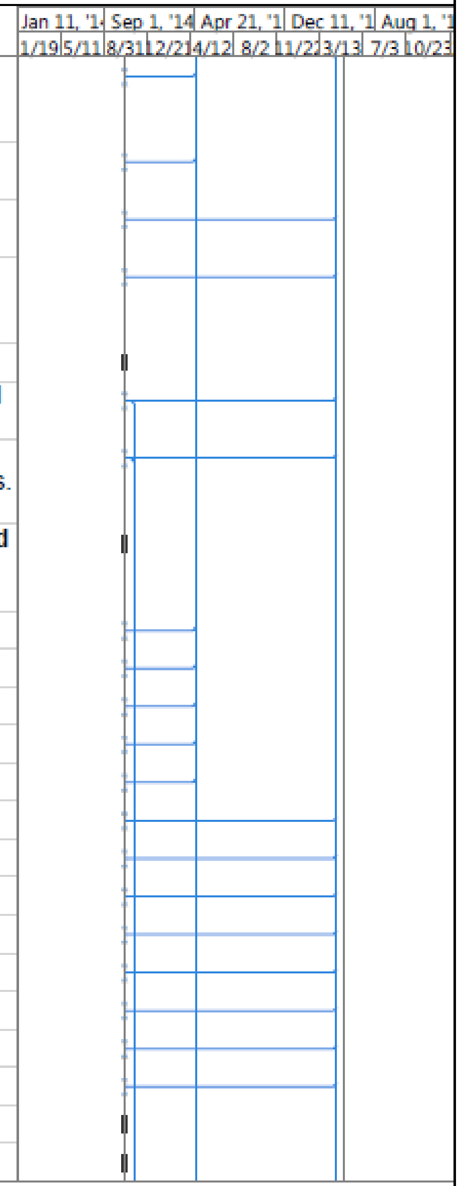
Page 2

ID	Task Name
48	Design and study feasibility of novel sensor architectures.
49	Design and test early prototypes for sensor detection of oil under ice.
50	Design and test early prototypes for novel electro-optical sensors.
51	If patentable complete provisional patent application, then publish Year 1 results in peer-reviewed venue.
52	**II.2.d PROJECT - New class of propeller-driven Long-Range AUV for Under Ice Mapping of Oil Spills and Environmental Hazards.**
53	Completion of augmented AUV simulator and test scenarios addressing high-risk elements, including navigation and sensing systems, demonstrating capabilities in Alaskan waters. (May 1, 2015)
54	Plan a navigation testing mission to test proposed strategy for mitigation of the risks associated with under-ice and high-latitude operations under-ice and high-latitude operations. (June 10, 2015)
55	Completed building/acquisition and delivery of a Tethys AUV.
56	Plan and perform the navigation testing mission.
57	Process the data from the testing mission.
58	Plan an observation mission in the Berring sea.
59	Equip the AUV for the planned observation mission.
60	Perform the planned observation mission.
61	**II.4 THEME 4 - INTEGRATED EDUCATION**
62	**II.4.a PROJECT- Arctic Education: Implementing the Arctic Strategy in Training**
63	Developed online knowledge based modules for the ICE Navigation STCW IMO model course. (June 30, 2015)
64	Developed simulator based practical assessments to be included in the instructor manual for a new ICE Navigation STCW IMO model course. (June 30, 2015)
65	Completed a pilot delivery of the IMO model course for selected commercial mariners transiting US Polar waters (June 30, 2016)
66	Completed adaptation blended online delivery of two 2.5 day classroom-based Maine DHS/FEMA approved courses and elements from EMO Ops DHS/FEMA course into ONE Alaskan Maritime First Responder course, "Command Strategies and Tactics for…."
67	**II.4.b. PROJECT- Minority Serving Institutions (MSI) outreach**
68	Establish potential MSIs to participate in the CMR at the "Institute on Teaching and Mentoring" conference sponsored by the Compact for Faculty Diversity.
69	Provide names of potential graduate students from the "Institute on Teaching and Mentoring" conference sponsored by the Compact for Faculty Diversity.

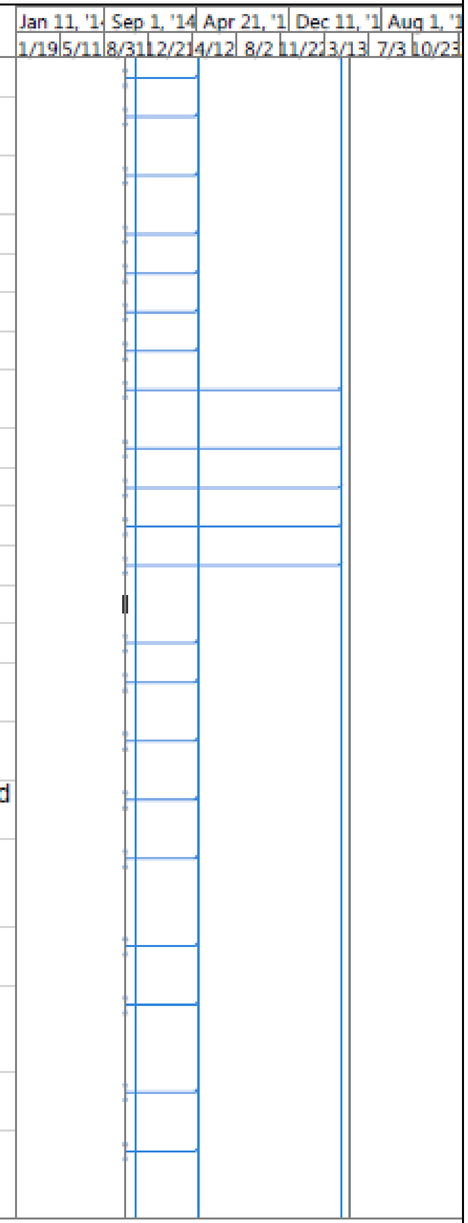
Jan 11, '1 | Sep 1, '14 | Apr 21, '1 | Dec 11, '1 | Aug 1, '1
1/19 | 5/11 | 8/31 | 12/21 | 4/12 | 8/2 | 11/22 | 3/13 | 7/3 | 10/23

ID	Task Name
70	Create and finalize plans for a "Diversity Day Conference" for students and faculty participants at UAA to be held Year 2.
71	Create a draft of the MSI Strategic Plan for the CMR, together with the Strategic Planning Committee.
72	Sponsor a "Diversity Day Conference" for students and faculty participants at UAA.
73	Complete and implement the MSI Strategic Plan.
74	**THEME 3: E2E SCENARIO 2 - Arctic Oil Spill Simulation**
75	**II.1 THEME 1 - MARITIME DOMAIN AWARENESS PROJECT**
76	**II.1.b PROJECT - High Resolution Modeling of Arctic Sea Ice and Currents**
77	Complete a survey of data products that may be used as forcing to drive HIOMAS or as open boundary conditions;
78	Complete plan on model configuration.
79	Completion of HIOMAS on a relatively coarse resolution for efficient resolution for efficient testing.
80	**II.1.c PROJECT- Oil Spill Modeling for the Bering, Chukchi, and Beaufort Seas.**
81	Run GNOME model using existing arctic location files/Simulations of selected oil spill scenarios with GNOME model (based on existing location files).
82	Create "Diagnostic Save Files" or location files for the GNOME model using high resolution output from Univ. of Washington's high resolution ocean and sea ice model/High resolution "Diagnostic Save Files" or location files.
83	Run GNOME model using high resolution location files for selected oil spill scenarios/Comparison of high-resolution GNOME model with conventional GNOME model.
84	Investigate various possible data assimilation strategies for integrating sensor data into GNOME model framework/Preliminary integration of oil spill data into GNOME model framework.
85	Rev 1: Preliminary work to integrate oil spill sensor data into GNOME modeling framework.
86	Rev 2: Preliminary work to integrate oil spill sensor data into GNOME modeling framework.
87	**II.1.d PROJECT- Real-Time Storm Surge and Coastal Flooding Forecasting for Western Alaska**
88	Development of an operational storm surge and coastal flooding model for the YK Delta/real-time forecasts of surge and flooding in the YK Delta area.
89	Comparison of measured and calculated water levels/assessment of the model performance.
90	Development of an operational storm surge and coastal flooding model for the Norton Sound/real-time forecasts of surge and flooding in the Norton Sound area.
91	**II.1.e PROJECT- Identifying, tracking and communicating sea-ice hazards in an integrated framework.**

ID	Task Name
92	Ice vector product: MDA and response efforts by USCG D17 and NOAA ERMA can draw on research products and guide development of operational products by federal agencies/private sector.
93	Mean velocity fields for model validation: Emergency/spill response modeling and observing components of CMR are fully aligned with respect to forcing and validation data.
94	High-precision ice deformation: The suitability for integration of high-precision GPS data in the context of MDA and threat monitoring as well as spill response is evaluated.
95	North Slope/Barrow CMR Testbed: build leadership role in leveraging existing observing and logistics resources to create a framework for hard/software, sensor and system evaluation and operational testing in a representative Arctic setting.
96	**II.1.f PROJECT- Mobile Maritime Domain Awareness using HFR in Remote Settings**
97	RPMC could be at TRL-9 by the end of Year 3 or 4 so that HFR –RPMC systems can be rapidly deployed under emergency situations.
98	Existing projects (funded by other agencies) will provide processed HFR data as requested for emergency/spill response modeling and observing components of CMR that lead to situational awareness. We will provide these data to the extent possible assuming
99	**II.1.g PROJECT- Monitoring intentional and unintentional catastrophic events: detecting oil spills and sea ice properties through measurements of the C and H2O isotope geochemistry in winds.**
100	Instruments ordered
101	Station siting secured with the Port of Anchorage
102	Winterized housing for the devices secured, power delivery secured,
103	Station installation, instruments deployment, instrument calibration,
104	Instruments operational, data streaming to the COE Headquarters.
105	Station instruments ordered
106	Station siting secured with the University of Anchorage in Nome,
107	Winterized housing for the devices secured, power delivery secured,
108	Station installation, instruments deployment, instrument calibration,
109	Instruments operational, data streaming to the COE Headquarters.
110	UAV's arriving on site,
111	Initial testing in Port of ANC area and fitting a UAV with a C-sensing device.
112	UAV flights in the Port of Anchorage area.
113	**II.2 THEME 2 - MARITIME TECHNOLOGY**
114	**II.2.a PROJECT - Integrated Intelligent System of Systems.**



ID	Task Name
115	Completion of a scenario and demonstration design to illustrate its capabilities.
116	Design and implementation of the 4D/RCS and its code within the scope of the demonstration scenario.
117	Completion of the VVT for demonstration scenario the 4D/RCS, IISoS, and integration with MSARS
118	Successful completion of the scenario demonstrations.
119	Documentation for the 4D/RCS (e.g., a user's manual) and IISoS.
120	Establish necessary connections with the portal of USCG in Juneau.
121	Successful incorporation of data fusion methods developed by HSARPA.
122	Incorporation of additional sensors that includes CBONs, satellite, UAV, Smart-Cam, and other sensor networks.
123	Completion of additional scenario and demonstration design.
124	Knowledge representation and development to act upon additional sensor inputs and their VVT.
125	Successful completion of the new scenario demonstrations.
126	Write and submit project results to peer-reviewed venue.
127	**II.2.b PROJECT- SmartCam Annual Work-plan Smart-Cam [Computational Photometer]**
128	Acquire components to build at least one proof-of-concept for bench testing.(3 months)
129	Achieve capabilities to measure power consumption and battery characteristics for dual channel visible and visible+IR configurations.(6 months)
130	Install OpenCV on embedded Linux for lifetime testing with image fusion – visible + LWIR (3 months)
131	Complete testing of an openCV embedded Linux lifetime with stereo visible mapping (disparity images and point cloud).(6 months)
132	Test and develop/refine Linux driver in V4L2 stack (Video for Linux, 2nd Edition) for NTSC-to-USB acquisition systems and document to improve custom PCB design for NTSC-to-FPGA-to-USB design in progress (future phases).(6 months)
133	Test uplink of images and streaming video over wireless b/g/n 802.11 for use in port environments and determine impact on power efficiency and battery lifetime.(6 months)
134	Define both software power saving options for TI-OMAP (Texas Instruments Open Media Applications Platform) and the Altera FPGA custom PCB in development for future phases.(6 months)
135	Deliver documentation and instructions for building a test configuration for the Port of Anchorage for field testing in future phases.(6 months)
136	Present finding to University of Alaska Anchorage and submit peer-reviewed paper on power efficient Arctic sensor designs using low-cost-off-the-shelf components at a national or international conference or in a journal . (6 months)



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137	Incorporate FPGA or co-processor into image processing operations and refine power characteristics. (6 months)	
138	Complete multiple field tests at the Port of Anchorage.(9 months)	
139	Test capabilities in a variety of imaging bands for applications including detection of oil under sea ice. (12 months)	
140	Publish Year 1 results in conference or journal. (12 months)	
141	**II.2.c PROJECT- Low-Cost Wireless Remote Sensors for Arctic Monitoring.**	
142	Develop communication protocol for ad-hoc sensor network.	
143	Design sensor platform for Port of Anchorage scenario.	
144	Measure power, data, and communication characteristics for sensors deployed in test bed.	
145	Complete analysis of data received on COE server that ultimately will interface with the Integrated Intelligent System of Systems.	
146	Deliver plan for building sensors and their configuration.	
147	Submit invention disclosure for any new IP, apply for provisional patent.	
148	Submit for publication.	
149	Design sensors for operation in more remote environments.	
150	Incorporate communication protocols and electronics for remote sensors.	
151	Design and study feasibility of novel sensor architectures.	
152	Design and test early prototypes for sensor detection of oil under ice.	
153	Design and test early prototypes for novel electro-optical sensors.	
154	If patentable complete provisional patent application, then publish Year 1 results in peer-reviewed venue.	
155	**II.2.d PROJECT - New class of propeller-driven Long-Range AUV for Under Ice Mapping of Oil Spills and Environmental Hazards.**	
156	Completion of augmented AUV simulator and test scenarios addressing high-risk elements, including navigation and sensing systems, demonstrating capabilities in Alaskan waters. (May 1, 2015)	
157	Plan a navigation testing mission to test proposed strategy for mitigation of the risks associated with under-ice and high-latitude operations under-ice and high-latitude operations. (June 10, 2015)	
158	Completed building/acquisition and delivery of a Tethys AUV.	
159	Plan and perform the navigation testing mission.	
160	Process the data from the testing mission.	
161	Plan an observation mission in the Berring sea.	

ID	Task Name
162	Equip the AUV for the planned observation mission.
163	Perform the planned observation mission.
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165	**II.4.a PROJECT- Arctic Education: Implementing the Arctic Strategy in Training**
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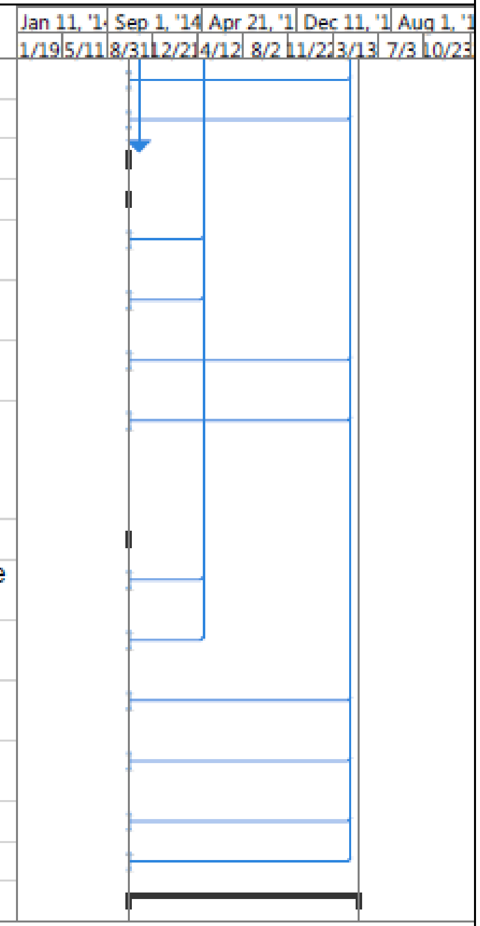
175	Sponsor a "Diversity Day Conference" for students and faculty participants at UAA.
176	Complete and implement the MSI Strategic Plan.
177	**Scenario 3: Future Research**



Appendix B

US Maritime Domain Awareness Top 20 Challenges

Challenge #	U.S. MDA Challenge Title
1	Collection for Non-Emitting and Uncooperative Vessels
2	Fusion and Analysis for Non-Emitting and Uncooperative Vessels
3	National MDA Enterprise Assessment
4	Understanding Maritime Activity
5	Determination of Anomalous Behavior
6	National MDA Strategy Development
7	Maritime Personnel Security Information
8	Shared Situational Analysis Capability
9	Fusion and Analysis for Cargo Data
10	MDA Information Collection Requirements Definition and Planning
11	Collection for Cargo Transiting Internationally
12	Fusion and Analysis for Maritime Personnel
13	Vessel Identification and Tracking
14	Domestic Sensor Supply and Deployment Shortfall
15	End-to-End Connectivity for the MDA Community
16	MDA Collaborative Tools Development
17	Enterprise Alignment of the National MDA Effort
18	MDA Network Management Services
19	MDA Information Assurance and Security Procedures
20	Non-Standard Collection on Safety of Life at Sea (SOLAS) Vessels

TABLE 1. U.S. MDA CHALLENGES

Appendix C

Acronyms

4D/RCS	Four dimension/real-time Control System
ACOMS	Acoustic communication
ADCIRC	Advanced Circulation Module
ADCP/DVL	Accoustic Doppler Current Profiler/Doppler Velocity Logs
ADIOS	Automated Data Inquiry for Oil Spills
AHP	Analytic Hierarchy Process
AIS	Automatic Identification System
AOOS	Alaska Ocean Observing System
ASCE TCCRE	American Society of Civil Engineers Technical Council on Cold Regions Engineering
ATV	All-Terrain Vehicle
AUV	Autonomous Underwater Vehicle
AVTEC	Alaska Vocational Technical Center
BESTMAS	Bering Ecosystem Study ice-ocean Modeling and Assimilation System
C	Carbon
C3	Command, Control and Communications Networks
CBONS	Community-Based Observer Networks
CBONS-SA	Community-Based Observer Networks for Situational Awareness
CMOS	Common Metal Oxide Substrate
ADAC	Center for Maritime Research
CO2	Carbon Dioxide
COE	Center of Excellence
COE/D	Center of Excellence Director
COE/ED	Center of Excellence Executive Director
COP	Common Operating Picture
COPE	Coastal Ocean and Port Engineering
COTS	Commercial off-the-shelf
CSTME	Command Strategies and Tactics for Marine Emergencies
CSTME	Command Strategies and Tactics for Marine Emergencies
CTD	Conductivity, Temperature and Depth (sensor instrument package)
DARPA	Defense Advanced Research Projects Agency
DEC	State of Alaska Department of Conservation
DHS	Department of Homeland Security
DHS/OUP	DHS Office of University Programs
DSP	Digital Signal Processor
E2E	End-to-End
EMR	Emergency Medical Responder
EMS	Emergency Management Systems
EOC	Emergency Operations Center
ERMA	Environmental Response Management Application

ET-SURGE	Extra-Tropical Surge
FBI	Federal Bureau of Investigation
FEMA	Federal Emergency Management Authority
FOA	Funding Opportunity Announcement
FPGA	Field Programmable Gate Array
FRAM	Ferroelectric Random Access Memory
GLMA	Great Lakes Maritime Academy
GNOME	General NOAA Operational Modeling Environment
GPS	Global Positioning System
H	Hydrogen
H2O	Water
HBCU	Historically Black Colleges and Universities
HF	High Frequency
HFO	High Fidelity Observer
HFR	High Frequency Radar
HIOMAS	High-resolutation Ice-Ocean Modeling and Assimilation System
HP	Hewlett Packard
HSARPA	Homeland Security Advanced Reseasrch Projects Agency
HYCOM	Hybrid Coordinated Ocean Model
IABP	International Arctic Buoy Program
IACUC	Institutional Animal Care and Use Committee
ICE	Immigration and Customs Enforcement
IISoS	Integrated Intelligent System of Systems
IMO	International Maritime Organization
IRB	Institutional Review Board
ITAR	International Traffic in Arms Regulations
LRAUV	Tethys Long-Range AUV
LWIR	Long Wavelength Infrared
MBARI	Monterey Bay Aquarium Research Institute
MDA	MacDonald, Dettwiler and Associates Corporation
MEMACE	Maine Maritime Academy Continuing Education
MODIS	Moderate Resolution Imaging Spectroradiometer
MOM	Merit of Measure
MSARS	Maritime Situational Awareness and Response Support
MSI	Minority Serving Institutions
NAIS	Nationwide Automatic Identification System
NAMEPA	North American Marine Environment Protection Association
NCEP	National Centers for Environmental Protection
NIST	National Institute of Standards and Technology
NOAA	National Oceanic and Atmospheric Administration
NSIDC	National Snow and Ice Data Center
NWS	National Weather Service
O	Oxygen
OODA	Observe-Orient-Decide-Act

OpenCV	Open Computer Vision
ORGS	Office of Research and Graduate Stucies
ORR	Office of Response and Restoration
ORR	Office of Response & Restoration
OTS	Off-the-shelf
PCB	Printed Circuit Board
PDO	Project Development and Oversight
PI	Principle Investigator
PM	Program Manager
POA	Port of Anchorage
POAC	Port and Ocean Engineering in Arctic Conditions
R&T	Research & Technology
RCR	Responsible Conduct of Research
RDC	Research and Development Center
RDT&E	Research Development
ROMS	Regional Ocean Modeling System
RPM	Remote Power Module
RPMC	Remote Power Module Compact
SC	Steering Committee
SCADA	Supervisory Control and Data Acquisition
SES	Social-Ecological System
SOP	Standard Operating Procedure
SPC	Strategic Planning Committee
STCW	Standards of Training, Certification and Watchkeeping International Maritime Organization
TI-OMAP	Texas Instruments Open Media Applications Platform
TPIC	Transition Planning and Implementation Committee
TRL	Technology Readiness Level
UAA	University of Alaska Anchorage
UAV	Unmanned Aerial Vehicle
UGV	Unmanned Ground Vehicles
USB	Universal Serial Bus
USBL	Ultra-short Baseline
USCG	U.S. Coast Guard
USCG D17	U.S. Coast Guard District 17
USV	Unmanned Surface Vehicles
USV	Unmanned Surface Vehicles
UUV	Unmanned Underwater Vehicle
UW	University of Washington
VHF	Very High Frequency
VPRGS	Vice Provost for Research and Graduate Studies
VVT	Verified, Validated and Tested
WHOL	Woods Hole Oceanographic Institution
YK Delta	Yukon Kuskokwim Delta